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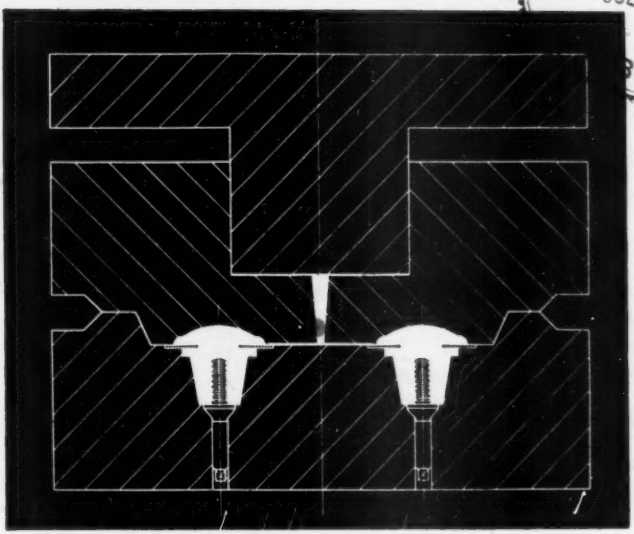

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Vol. IX. No. 97 JUNE, 1945

Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

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NOTICES

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SAVE PAPER

More than ever is paper waste required for our war industries. Waste paper makes munitions in a hundred forms—from shell cases to aeroplane parts.

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EDITORIALS

I.C.I. Story

LORD McGOWAN, chairman of Imperial Chemical Industries, Ltd., has now lifted a corner of the veil that shrouded many of the activities of his vast company during the war years. We doubt whether any other industrial organization can show as fine a record.

Most of us know, broadly speaking, what this company manufactures in peace-time: fertilizers, explosives, general heavy chemicals and some fine chemicals, dyestuffs, paints, plastics, petrol, copper and brass tubes, etc.

In war-time, the production of these rose to dizzy heights as a matter of course, but because of its experience and, what is more important, because of the research organization on which all its production is based, the company was able to render new services in experiment, development and manufacture. A new plastic explosive was developed for a number of devices which ranged from the sticky bomb and the spigot mortar and bomb to the "Flying Dustman," which was mounted on a tank. Another I.C.I. development was the P.I.A.T., of which it may be very proud. In another category, the soup-heating cartridge was, perhaps, of equal importance.

Other little-known activities included the erection of a new factory for manufacturing metal fuel tanks, the development of the technique of making fuel tanks bullet-proof, and the production of Mepacrine, the synthetic drug which supplied deficiencies made by our vanished quinine sources. Penicillin was manufactured in large quantities and so were the two new triumphs of research, "Gammexane," the new insecticide, more effective even than D.D.T., and "Methoxone," the new weed killer, which leaves crops quite unharmed.

Of plastics we need not speak much since all our readers know of I.C.I.'s record in this sphere and which has culminated most recently in the production of polythene, in our opinion, as great an industrial achievement as nylon and one which may yet compare with the latter in economic value. Certainly its discovery and invention played no small part in the outcome of the Battle of Britain and in the defeat of the air attacks that followed.

Nationalization

IN his address, Lord McGowan also spoke of the often-expressed desire in certain quarters to bring big and important industries under State control, and of his antagonism to such ideas, which stress the danger of big groupings.

Our own memories of this group go back to the days in the middle 1920's when Nobel's, Brunner Mond, British Dyestuffs and United Alkali were first joined as I.C.I. There was much pother at that time, but what a relief it was to many of us observers who saw in this union the direct answer to the world chemical hegemony of the German Interessen Gemeinschaft für Farbenindustrie! Lucky indeed are we that this country had an I.C.I. in 1939. And to those who look upon big business as always being caught in the Germanic toils, we have never yet had it suggested that the Germans knew all about polythene, even though it was produced here before the war. We believe that no captured German electrical device has yet been found to contain any of this plastic—and Germany needed such a one badly.

The reason for our defence of chemical concerns, large or small, and for their maintenance as free entities, lies in a belief that, in matters of research, bureaucracy has neither the understanding nor even the desire to comprehend its meaning. How can we trust a bureaucracy with a Treasury that doles out such pitifully small sums to universities for research that it is only by the larger donations of private firms that such

work can continue? Can bureaucracy understand the patience required for research work, the years of failure that almost always precedes success? Will bureaucracy "gamble" with public money as does private ownership with its own? We think the answer is "No," at least until that far-distant time when Governments will contain competent scientists equal in stature to its other components, to advise and make adequate provision for research and technical development.

Aluminium Exhibition

ELSEWHERE in this issue we publish a few photographs of the first war exhibition of an industry about to enter the field of "almost peace-time" action. Aluminium has come a long way since 1845, when it was almost a rare metal at £20 per pound, and its protagonists intend that it shall take an ever-growing share in the markets of the world. We know enough of the great part played by the metal during the war to wish this effort success.

But these notes have not been written merely as a pæan of praise for aluminium. Our own plastic materials will make as attractive and certainly more colourful and warmer a show when the appropriate time comes. Rather do they, with the photographs, hope to give some indication of a new trend in industry, which we have long advocated in this journal—the necessity to examine all materials of construction, and to promote their marriage when and where such a union will result in an improved product. This process must not be an unwilling one nor a desperate measure to gain a temporary advantage, but must be the result of a carefully planned consideration of the chemical, physical, mechanical properties apposite to the problem.

Perhaps without straining the reader's credulity too greatly, we may say that these suggestions, in the false teeth of considerable opposition, we first put forward in these offices, and we are slowly seeing their common acceptance.

It is present in some of the aluminium exhibits, where a plastic has been used for a very good reason not far to see.

As yet it is only the germ of an idea, but germs have a habit of growing rapidly into colonies.

Master-key Industries

WE have received a report of a discussion at a recent meeting of the British Association of Chemists on the subject of the safeguarding of master-key industries, a matter which is worthy of the support or, at least, the closest examination by all scientifically controlled industries.

Mr. Norman Sheldon, F.R.I.C., the prime mover in the discussion and an expert on chemical ware, described the necessity to secure for those industries he calls master-key industries, which include the production of scientific glassware and instruments, the complete home market. This step, he states, should be taken to prevent a recurrence of the world-wide control exercised by the Government-subsidized German industry, which resulted in the appalling shortage of such ware and of skilled workers in this country in 1939. These products are so important in war-time because they provide the means of directing and controlling our armed forces. They are equally important in peace-time to improve our standard of living and to offer the rest of the world many things that they cannot make for themselves. We should also thereby create a great number of highly skilled and highly paid men for this work and a training ground for the future.

Colonel Bristow, of Low Temperature Carbonisation, also spoke for the necessity of increased protection of this important industry. He said: ". . . We are now, I hope, going to develop rapidly the plastics industry and the possibilities of synthetic rubber. If any of you take the Plastics Journal you will read about the evolution of these new products . . . and how the industry is working hand in hand with the scientific-instrument manufacturer and with still more scientific apparatus."

"Post-formed" Phenolic Resin Laminated Plastics

By E. E. HALLS

IN the March and April issues of "Plastics," brief but comprehensive notes were given upon the subject of "pre-formed" plastics. These aroused considerable interest over here because, although these materials and the articles produced from them have apparently reached an advanced stage of exploitation in America, there is little or no information published in technical journals at home from which to glean how far progress, if any, has extended in this country. Much the same state of affairs exists with respect to the special thermosetting classes of phenolic resin laminated plastics that have been developed in America for post-forming purposes, that is, sheet stock that can be worked hot in simple shaping tools for bending or forming or bending, pressing or drawing, and which responds to these orthodox processes of engineering in a manner that is somewhat analogous to the performance of the metals under similar circumstances. It is thought that an abstract from recent literature of American origin is opportune at the present time.

It will have been noted that the pre-formed plastics use a material which, in effect, consists of a paper half-stuff or similar fibrous pulp impregnated with the synthetic resin of the thermosetting phenolic type. This is employed in the condition of a water suspension, being pre-formed to shape by directly filtering or screening through a fine copper metal gauze fashioned closely to the contour of the article that is to be produced. The article is then carefully stripped from the tool and dried. It is then pressed accurately to shape and dimensions in a heated mould, this curing the resin to give a rigid component relatively stable dimensions. These notes are repeated in order to stress at the outset the primary difference between the pre-formed and the post-formed plastics.

The first important reference to laminated plastics for hot post-forming was probably the announcement of "Micarta 444" by the Westinghouse Electric and Manufacturing Co. of America. Some account of its nature, properties and potential uses were given in a symposium on plastics by, and reported in, "Electrical Engineering," July, 1944, vol. 63, No. 7, page 274. Further details were presented in the "Iron Age," 24/8/44, p. 49, and the following information appertaining to this material is taken from this source.

The ordinary grades of Westinghouse phenolic resin laminated, which are known by the trade designation of "Micarta," can, of course, be made in the form of simple shapes, such as plate or sheet, rod, tube, angle and channel. More intricate contours are naturally possible, but, on account of the expensive steel tools that are involved, they are not really practicable in an economic sense unless the quantities required are very large and a production schedule over a reasonably long period is assured. The special laminated material was a development over a period of time to meet this objection. The first object was thus to provide a raw material in the form of sheet that could be fabricated into relatively simple shapes by means of inexpensive tools, the material in the article so formed to retain all the desirable properties of a high grade of phenolic resin laminated sheet. The second object, one which was of immediate practical concern, was to fulfil the requirements of the aircraft industry by providing a raw material suited to the quick fabrication of shaped components. From this application the field for the material has been

extended, and it has usefully been employed for trim tab fairings, fuselage tail-wheel-housings, aviators' chart cases, wing gun ammunition feeds and ejection chutes, accumulator covers and the like. Its success, at least from the economic standpoint, is accounted for by the fact that tools are inexpensive for the intricate shapes concerned, because they can be readily and cheaply constructed from wood, concrete or phenolic resin laminated plastic itself.

Micarta 444 is thus a phenolic resin laminated plastic sheet material in the partially cured condition. By heating it rapidly to a temperature of approximately 275 degrees F., this material attains a plastic condition that permits of forming and completion of the cure, so that when the product cools to normal temperatures it exhibits the average properties and appearance of phenolic resin laminated sheet material. The medium for heating can be selected from any available source that will satisfy the requirements just stated, and accurately and rapidly raise the temperature of both the surfaces of the material to the proper forming temperature. The optimum value of this operating temperature can readily be determined for each specific job by means of a preliminary trial, and it must be accurately maintained by thermostatic control and timing devices as necessitated by the nature and intricacy of individual jobs. The common heating methods include parallel hot plates, oil or liquid metal baths, hot air ovens, infrared radiant heating and dielectric heating by means of high frequency. Naturally, the heating period is dependent upon the thickness of the sheet material, so this, too, must be determined by practical trial. It can quite simply be arrived at by heating a sample test strip.

For deep drawing, the sheet or strip of Micarta 444 is preheated as described, and it is placed in the tool immediately upon removal from the source of heat. The first contact is made with the draw ring, which must hold the material firmly during the drawing operation. At the completion of the draw, the material must be held in position in the mould until the temperature has fallen below the softening point. It would thus appear from this that complete curing or thermosetting is not achieved. The potentialities of the material in drawing processes can be seen from the data given for depths of draw in certain thicknesses of material, viz., from $1\frac{3}{4}$ ins. for 1/32-in. thickness to $1\frac{1}{4}$ ins. for $\frac{1}{16}$-in. thickness stock. Such draws are accomplished without any signs of cracking, wrinkling or delamination.

For drawing and shaping without the use of a draw ring, which is possible, the mould is set for a draw of 10 per cent. in either direction of the weave of the fabric cloth of the lamination, or for as much as 40 per cent. in the diagonal direction. Regarding the inside radii of bends, for 1/32-in. thick material the radius may be as small as 1/32 in., while for a material thickness of $\frac{1}{16}$ in. it can be as low as 3/32 in. As for clearance between the sides of the pressing block and of the forming block, an allowance of 0.010 in. greater than the maximum thickness of the raw material should be made. It is necessary to grease both of the blocks before using them, the exception being when hot oil has been employed as the heating medium, the retained oil then sufficing for purposes of lubrication.

In Table 1 are given some of the properties of Micarta 444 for this material in two colours, tan and dark green. Mechanical, electrical, physical and thermal characteristics are included, so that a quite comprehensive picture of the nature of this newcomer can be obtained. It will be seen that the mechanical strength values are normal for this class of material, the electrical strength is of good order, and water absorption is not unduly high for material in these thin thicknesses.

Frank Sullivan, of the engineering department, the Formica Insulation Co., Cincinnati, Ohio, sheds further light on this type of specially manufactured laminated phenolic resin sheet material in an article entitled " Post-formed Laminated Phenolic Plastics," which appeared in " Metals and Alloys," February,

Table 1.—Properties of Micarta 444.

Properties	444 tan		444 dark green	
	With grain	Cross grain	With grain	Cross grain
Tensile strength	13,000	11,000	13,000	11,000
Modulus of elasticity	0.9×10^6	0.9×10^6	1.1×10^6	1.1×10^6
Flexural strength flatwise	19,000	16,000	24,000	18,000
Flexural strength edgewise	19,000	16,000	24,000	18,000
Izod impact strength flatwise, ft. lb./1 in. width	2.0	2.3	6.0	5.0
Izod impact strength edgewise, ft. lb./1 in. width	1.3	0.7	3.0	2.0
Compressive strength flatwise	33,000		37,000	
Compressive strength edgewise	16,000		20,000	
Dielectric strength short time	240 volts per mil.		200 volts per mil.	
Dielectric strength step by step	130 volts per mil.		100 volts per mil.	
Specific gravity	1.37		1.39	
Water absorption (A.S.T.M.) 3×1×1/16 (weight gain in 24 hrs.)	6.0		4.5	
Thermal conductivity (approx.) cal./sec./deg.C./sq.cm./cm.	0.00061		0.00061	
Specific heat (approx.)	0.4		0.4	
Thermal coefficient of expansion per deg. C. (approx.)	31×10^6		31×10^6	

Note: Properties' data are average value based on tests made by A.S.T.M. method. Samples were tested in the "as received" condition at approximately 70° F. temperature.
Micarta 444 in tan has greater tensile elongation at the forming temperature. The tan grade has an ultimate elongation of 10 per cent. lengthwise, 12 per cent. crosswise, and 40 per cent. diagonally. Dark green 444 will elongate 9 per cent. lengthwise, 9 per cent. crosswise, and 25 per cent. diagonally.

1945, page 392. This indicates that several American manufacturers are producing this class of material, and that the product meets the requirements of a material that can be drawn or shaped inexpensively into articles that were previously made by moulding from plastic moulding powders. The following information and illustrations are taken from this source and they give some idea of the possible many new applications that can be built around a material which possesses its own distinctive properties.

Sullivan states that the term post-forming is usually employed to designate the procedure by which this material is treated after the laminations have been heat-set, and that it is simply the reshaping of a cured laminated sheet. This forming is accomplished by heating the sheet rapidly to a high temperature, then quickly bending or drawing it into the new contour and holding it in this shape until it has cooled.

Unfortunately, the author is not as clear as could be desired in his information upon the compositional nature of this new material. He refers to the isolated instances of bending operations upon thermoplastic sheets in the past, such as the heating and bending of phenolic resin laminated, or the bending of urea laminates after soaking in warm water, examples with which most users of these plastics have familiarized themselves from time to time. Nevertheless, there is no doubt that the conditions necessary for the full development of these bending possibilities had not been previously understood, and Sullivan gives William Beach, of the North American Aviation Corporation, the credit of realizing the possibilities and developing the new high-temperature technique.

With regard to the composition of the material, Sullivan states that thermoset phenolic resin sheets which have been laminated are used. The necessary quality of formability is imparted by the retention of a certain degree of thermoplastic properties. This feature is made use of by heating the piece to be formed very rapidly. It is very important that the object should be heated to temperature with speed, because further polymerization or thermal setting occurs during the heating period, and this detracts naturally from the formability of the material. The higher the temperature the more plastic will the material become, but there is obviously a limit, this limit being the blistering point.

The material is stated to be a special grade of phenolic resin canvas laminated, and post-forming sheet is available which has the characteristics of the regular American standard Grade C material. The latter is a canvas-base laminate designed for structural applications in which high tensile and transverse strength are required. It has not been found necessary to detract from the normal good qualities in order to induce the properties of formability. The forming quality can be supplied in sheet sizes up to 36 ins. by 96 ins., and the most commonly used thickness is $\frac{1}{16}$ in. What happens in the material in use is that the exposure to high temperature causes the sheet to soften before the chemical action of hardening really commences, this chemical action requiring time. With rapid heating and forming, the degree of polymerization that occurs before the article has taken its new shape is only slight, but, nevertheless, once it has been heated the material does lose some of its formability characteristic.

The analogy has been drawn between the post-forming of this laminate and the forming or drawing of metals. While this is true to some degree, at least with respect to the starting point in the form of a sheet of raw material and to the end product in the form of a shape, the actual technique is rather different from that associated with sheet-metal working. At the same time, the technique involved is a simple one to acquire, as well as one which is readily adaptable to a variety of production conditions. Primarily, there are four steps entailed in the transfer of the sheet to the shaped component:

(1) Cutting the blank shapes from the sheet.

(2) Heating the shape to the formable condition.

(3) Actual shaping.

(4) Cooling the shape before removing it from the tool.

With regard to the cutting of the material to shape in the first of these operations, the equipment and the skill that is required is dependent upon the intricacy of the article itself. For simple bending operations, the material may in many cases be sheared or sawn to the size required, dealing with several superimposed sheets simultaneously. On the other hand, if the size of the blank is not too great, and the production quantity involved is sufficiently large to justify it, then the pieces may be blanked, using a steel or a Kirksite die. For large pieces, especially if they are of intricate pattern, cutting on routing machines is advocated, this operation being much the same as when cutting aluminium-alloy sheet.

The second operation of heating the material to a formable condition must, it is admitted, depend in some measure upon the skill of the operator. It involves preliminary exploratory tests to establish the time of heating in the oven, operator's judgment to get this correctly to the optimum value, and, thereafter, its maintenance to a constant set of conditions for the whole of the subsequent working batch. Excessive time in the oven may cause blistering, while a deficiency of time will tend to result in cracking during the forming operation. Thus it is a question of acquiring a degree of skill in imparting the right degree of oven treatment and the right alacrity in removing from the oven and transferring to the forming jig.

Sullivan says that it is possible to determine the best temperature for the ultimate forming conditions by means of thermocouples actually embedded in the material. The sheet is, of course, actually heated from the outside, and, therefore, there must always be some temperature differential from the outside to the centre of the material. In very thin sheets this will be very small and may be negligible, but in sheets up to $\frac{3}{8}$ in. in thickness this differential can be as high as 35 to 55 degrees F., which is obviously appreciable and can by no means be ignored. However, a reasonable working margin is apparently available because Sullivan states that, disregarding the temperature differential, he finds that when the temperature of the sheet reaches 250 degrees F., it begins to soften slightly, and that it continues to soften and become more pliable until it reaches 350 to 355 degrees

F., at which temperature it begins to blister. Very little ability to form is exhibited at the 250 degrees F. temperature, but this forming ability rapidly increases until the blistering temperature is attained. Even if these temperature values are regarded as only of a comparative nature, they do yield a very good picture of the margin of formability, and, in this sense, they are quite significant.

For successful forming in repetition work, therefore, it is evident that the operator must work with the temperature of the material as close to the blistering point as is practicable. Further, taking into account the differential that must exist in temperature between the centre of the sheet and its surface, then the temperature of the heating medium must be so adjusted that the centre of the sheet is as hot as it is possible to get it without any overheating at the surface.

Time of heating is also a factor that must be given due attention and consideration. A rate of heating that is too slow will tend to cause the material to become dry and brittle, and, in consequence, formability will be decreased appreciably. Therefore, the additional statement can be made to the effect that the temperature of the heating medium must be such that the centre of the sheet shall be brought to the forming condition as rapidly as it is possible to do so without blistering the surface of the material.

The dimensional accuracy of components produced from post-forming quality of laminated sheet is not so good as it is with articles made by moulding from phenolic laminated sheet stock. It is fairly evident that dimensions are harder to hold in the post-forming process. For forming, the thickness is essentially uniform throughout; stretched sections vary only slightly in thickness. Square outside corners cannot be provided. At the same time, the post-forming method is a very attractive one. It is characterized by simplicity and adaptability, and for some shapes it is claimed to be definitely less expensive.

Sullivan points out that the Grade C canvas-base phenolic laminated sheet material is used almost exclusively for this post-forming laminate. In the drawing of complex shapes, the threads of the canvas straighten out, or they tend to crimp or to bias. Thus, when a cup is drawn, the threads at the bottom are stretched, those around the circumference are compressed, and those at an angle of 45 degrees to the drawing direction are drawn into a shape. However, threads maintain their original identity and do not break. The final component retains the original character of the sheet from which it was produced. The role of the threads in enabling the forming to occur will thus be noted; the development of an equivalent material from paper-base laminate still awaits solution.

In a good grade of post-forming canvas laminated sheet, it is stated that the percentage of strength in the direction of the threads is as much as 12, while along the diagonal it is as high as 30 per cent. Consequently, in cases in which extreme bends are required, they should

Fig. 1. — These examples of post-formed parts include simple bends, but also units that require drawing.

Fig. 2.—Post-formed parts, with a straight-bending form in the centre. Note resemblance of shapes to metal stampings.

be arranged in such a manner that they are located diagonally to the threads. It is a real advantage for the stretch to originate from the uncrimping of the threads. It prevents those local thin spots that are encountered with unfilled plastic sheet and which are experienced to a lesser degree with metal. The greater the stretch, the greater is the resistance, and, therefore, the stretch tends to distribute itself uniformly.

Again making a comparison with metal, it has been found in practice to be easier to draw this plastic than it is to draw a similar piece of metal. The laminate only requires one draw, whereas metal needs several drawing stages.

Other fundamental advantages over metal can be cited and are worthy of specific consideration. The vibration absorption characteristics of the plastic are always one of its great advantages; it is only one half as heavy as the aluminium-base alloys and exhibits greater chemical resistance; abrasion resistance is better than with the softer metals, and it does not tend to flower or petal out to the same degree as metal does when shot through. At ordinary temperatures, the plastic is resilient and stiff; once it has cooled from the tool, it will not dent, whereas metal, if it will draw, will dent under any circumstances.

In Fig. 1 are illustrated a group of post-formed plastic components, some of which have entailed only simple bending, while others have entailed an appreciable degree of drawing. The shell and box-shaped parts should be particularly noted. A further selection of types is included in Fig. 2, in which simple bends, stiffening forms and shallow draws are demonstrated. Finally, in Fig. 3, a typical post-forming set-up is shown. The bending block, the blank of laminate attached to the punch and the formed article are included.

This subject of post-forming is an interesting and intriguing one, and the availability of the raw material to respond to a process of this nature is an asset.

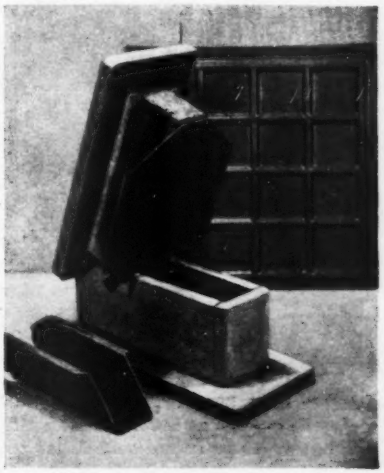
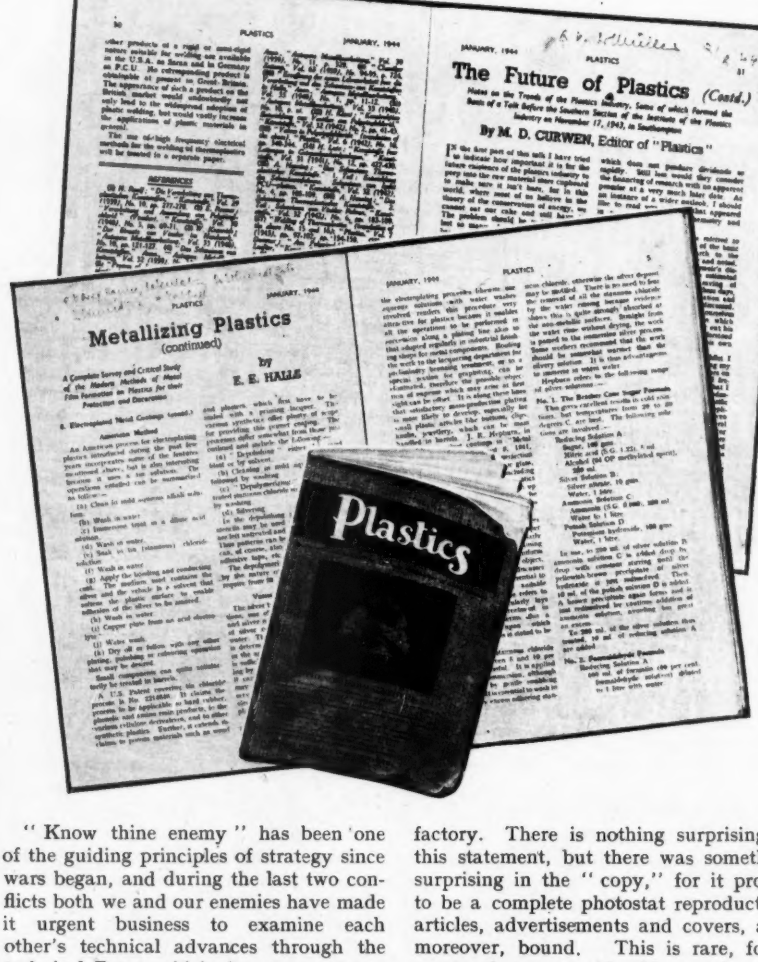


Fig. 3.—Forming tools, including bending block, laminated sheet and the finished formed part.

(With acknowledgments to "Metals and Alloys.")

NEWS FROM GERMANY



" Know thine enemy " has been one of the guiding principles of strategy since wars began, and during the last two conflicts both we and our enemies have made it urgent business to examine each other's technical advances through the technical Press, which, by one means or another, can always be obtained in some degree intermittent or continuous. The need for careful censorship is thus obvious.

A short time ago, a visitor to Germany informed us that he possessed a copy of " Plastics " he had found in a German factory. There is nothing surprising in this statement, but there was something surprising in the " copy," for it proved to be a complete photostat reproduction, articles, advertisements and covers, and, moreover, bound. This is rare, for it means that a considerable number had been so produced for circulation to various factories.

The pencilled notes seen above on the heads of the pages indicate that the copy had been circulated to Professor Koner, Drs. Schmidt, Schmid, Müller of various departments in the factory.

Silicone Resins and Plastics

By WILLIAM S. PENN, B.Sc.

New types of synthetic resins have been described. These are the silicones, and they have been shown to have excellent dielectric properties at high temperatures and under high humidity conditions. Six varieties have been described, ranging from moulding powders and varnishes, to rubbers and "bouncing putty." Their present and future applications have been indicated, and it has been shown that these are considerable.

IT is not very often, in the rapidly changing field of high polymers, that a completely new range of resins is announced. Developments there are, but different products are few. The silicones, however, are completely new and novel, at least industrially, although they have been known academically for over 70 years. They have extremely valuable properties, and fill a gap that has held up various aspects of electrical equipment development for many years.

No wonder, therefore, that they have been welcomed with open arms. They have such supreme properties of heat and moisture resistance that these two facts alone assure them of a ready market. Other valuable properties exist, however, and it will be the purpose of this article to describe present and possible future uses.

Many varieties of silicones are available, and the different types may be applied to such diverse fields as lubrication and the production of synthetic rubbers. They may be either thermoplastic or thermosetting, and the production of regular high - temperature mouldings is already in the advanced experimental stage. Varnishes are already well established, and these may be used as wire and cable insulants, impregnants, water repellants and the like.

It is obvious, therefore, that the excellent properties claimed are not exaggerated in any way and so their chemistry, methods of fabrication, properties and applications will be discussed in some detail, because it is felt that they will be used extensively once they become generally available.

The Chemistry of Silicones

The organic compounds of silicon were first made and examined in the period 1871-1874 by Friedel, Crofts and Ladenburg, who discovered that organo-metallic halides could be reacted with silicon halides to form organo-silicon compounds. Much more important than this, however, was the discovery by Kipping,[1] in 1904, that organic radicals could be attached to silicon with the aid of magnesium via Grignard reagents. The resultant organo-silicon halides may be hydrolyzed with water to the corresponding hydroxy organo-silanes, which may be condensed to polymeric substances.

This simple preparation is capable of indefinite extension. All the different types of silicones may be prepared by it, as will shortly be explained. The first attempts to produce silicones involved replacing some of the organic radicles by silicon in an organic chain. Slight improvements were thereby effected. No really new resin was produced, however, until the opposite was attempted, i.e., a silicon chain was substituted with organic radicals. In this manner the valuable properties of the inorganic materials are capable of translation to organic practice. In other words, the silicones are soluble in organic solvents which greatly extends their use.

The following example is one of many which could be given, and it may really be regarded as a prototype.

p-dibromo benzene is first reacted with magnesium

$$C_6H_4Br_2 + 2Mg \longrightarrow BrMgC_6H_4MgBr$$

This, reacted with silicon tetrachloride, gives:—

$$n\ Br.Mg.C_6H_4Mg.Br. + n\ Si.Cl_4 \longrightarrow (-C_6H_4-Si.Cl_2-)_n + 2n\ Mg.Br.Cl.$$

This compound can be hydrolyzed and condensed or reacted with ethyl magnesium chloride:—

$$(-C_6H_4-Si.Cl_2-)_n + nC_2H_5\ Mg.Br. \longrightarrow (-C_6H_4-\underset{\displaystyle Cl}{\overset{\displaystyle C_2H_5}{\overset{|}{\underset{|}{Si}}}}-)_n + nMg.Br.Cl.$$

If this is then hydrolyzed in ice-cold water the hydroxy derivative is formed

$$(-C_6H_4-\underset{\displaystyle OH}{\overset{\displaystyle C_2H_5}{\overset{|}{\underset{|}{Si}}}}-)n$$

The various extensions of these reactions are as follow:—

(1) A compound of the type R_3SiOH is produced, and this is only capable of condensation to the simple ether R_3 Si-O-Si R_3. This is non-resinous.

(2) A compound of the type $R_2Si(OH)_2$ is produced, and this is capable of condensation to thermoplastic derivatives only. These are permanently fusible—

$$-O-\underset{\displaystyle R_2}{\overset{|}{Si}}-O-\underset{\displaystyle R_2}{\overset{|}{Si}}-O-\underset{\displaystyle R_2}{\overset{|}{Si}}-$$

(3) A compound of the type $R\,Si(OH)_3$ is produced, and a three-dimensional system may be obtained.

$$-\underset{\displaystyle O}{\overset{\displaystyle R}{\overset{|}{\underset{|}{Si}}}}-O-\underset{\displaystyle R}{\overset{|}{Si}}-O-$$ This is thermosetting.

These examples, it will be noticed, lead to chains containing – Si – O – but with the example given above it is also possible to have carbon atoms in the chains.

$$-C_6H_4-\underset{\displaystyle O}{\overset{\displaystyle C_2H_5}{\overset{|}{\underset{|}{Si}}}}-C_6H_4-\underset{|}{\overset{\displaystyle O}{\overset{|}{Si}}}-$$

$$-C_6H_4-\underset{|}{\overset{|}{Si}}-O-\underset{|}{\overset{|}{Si}}-C_6H_4-$$

Thus an extremely complex series of materials may be built up. It is easy to see how the variety of products is obtained.

There is no point in giving further examples, since they obviously could be elongated indefinitely. As with all new products, an extensive patent literature is rapidly being built up around the silicones,[2] and care must, therefore, be taken in using them.

It should be noted that although the silicones are difficult, if not impossible, to obtain commercially, at the present moment, for experimental purposes, it is extremely simple to make them in any laboratory. The following example[3] is typical of the reactions which may be used:—

1.65 mols. of p-dibromobenzene in ether solution are caused to react with 3.45 mols. magnesium. The resultant phenylene-di-magnesium bromide is added with stirring to an ether solution of silicon tetrachloride and the mixture is heated under reflux for 30 minutes. The so formed phenylene silicon dichloride is then added with stirring to 1.32 mols. of the di-magnesium derivative of mixed isomeric dichloropentanes in ether solution and heated under reflux for two hours. The solution of organo-silicon complex is isolated by pouring into water, thereby dissolving out the magnesium salts. Evaporation of most of the ether yields an extremely viscous benzene soluble resin. Complete evaporation yields a solid, clear yellow resin with a non-tacky surface.

Types of Resins Available

There are several types of resins available, or at least it would be more correct to say that they are capable of commercial production, since they are very difficult to obtain at present. They will

be spoken of, however, as being freely available, since this will be possible so soon as the various war-time restrictions are removed.

The first type of resin is a liquid form. This may have a great variety of viscosities, boiling points, specific gravities, etc., all the other properties (to be described shortly) vary accordingly. It is permanently fusible and may be treated as an ordinary non-volatile liquid.

Closely associated with the liquid form is the grease type. This, too, is available in many different forms and is permanently fusible.

The third type available is that in the form of a varnish. This is thermosetting and may be baked to a hard film. It may be treated, and is available as any other varnish formulation.

Although the next type is not available commercially, it has been produced on an experimental scale, and it will not be long before it reaches the markets. This is a moulding powder. The silicones (of the binder type) have already been used to bind mica and various other veneers together.

The final formulation is a synthetic rubber. This is available in any consistency, hard or soft. Some can be vulcanized, but others are thermoplastic. A development of this is a plastic-elastic material. To the touch it is like putty, but it will bounce if dropped. The difference is due to the slow rate of application of stress in the first instance and the rapid rate in the latter instance.

It should be remembered that any of the above types may be modified to a great extent, and the possible variations are almost infinite. A great variety of properties are possible, and these will now be described.

Properties of Liquid Silicones

When the molecules of the silicones are allowed to grow in two directions only, the thermoplastic compounds are formed. Increasing chain length naturally increases viscosity, and so it is found that the liquid silicones are available in a large range of viscosities. Moreover, any particular viscosity is fairly constant over a wide range of temperatures, much more so than most liquids which are used for damping fluids and the like.

In appearance the new liquid silicones are clear and sparkling, water-white and very mobile. They are very inert, which makes them useful for many applications. Some indications of their general inertness and unreactivity will suggest possible uses. They are non-corrosive to metals and do not affect rubber or synthetic rubbers and organic plastics, although they are widely soluble in organic solvents (except water and the lower aliphatic alcohols). The materials are also resistant to oxidizing agents (including oxygen), mineral acids and various salts. They are also stable to heat and are chemically neutral (pH about 7).

Other valuable properties are as follow. They have a low surface tension (about 20 dynes/cm.), which means that they readily wet surfaces which are themselves made repellent to water. Above a viscosity of about 5 centistokes they are non-volatile and have lower flash points than equivalent petroleum oils. The liquids (viscosity 100 centistokes upwards) may be used at −40 degrees C. to 200 degrees C. Below this viscosity they may be used at temperatures under −55 degrees C.

Electrically the fluids are also very good. This actually applies to all the silicones, both liquid and solid. Table 2 gives some of the electrical properties of the silicones. One of the outstanding features in this instance is the low dielectric constant and low power factor over a wide frequency spectrum. Table 1[4] contains details of some of the properties of the liquid silicones.

Features to be noted are that in the low-viscosity range (these are more or less simple ethers, which are characterized as a class by their general chemical inertness) the rate of increase of value of the properties is great. At the higher viscosities, however, the properties tend to a limiting value.

Table 1.—Properties of Liquid Silicones.

Viscosity (centistokes) (25°C.)	Flash point °C.	S.G. 25°C.	Boiling point	
			Temp. °C.	Pressure mm. Hg
0.65	−1	0.7606	99	760
1.5	71	0.8516	192	760
5.0	132	0.918	120–160	0.5
50.0	282	0.955	Non volatile at 200°C. and 0.5 mm. Hg	
100.0	315	0.966	Non volatile at 200°C. and 0.5 mm. Hg	
500.0	329	0.972	Non volatile at 200°C. and 0.5 mm. Hg	
1,000.0	338	0.973	Non volatile at 200°C. and 0.5 mm. Hg	

Grease-type Silicones

The grease type of silicone may be regarded as essentially a development of the liquid type. In fact, if it is looked upon as a fluid with very high viscosity (speaking in terms of chain length), this is not far from being the case.

The properties of the higher viscosity liquids may, therefore, be treated in general as being very similar to those of the greases. This can lead to some peculiar effects. For instance, if the property (of the liquids) of not changing the viscosity a great deal over a wide temperature range is interpreted strictly, then the consistency of the grease should remain almost the same over the same range of temperatures. This is actually found in practice, since the grease remains as a grease even at high temperatures, in strong contrast to petroleum products which melt. Therefore, these greases may be used satisfactorily even at 200 degrees C. or possibly more. They are available in a wide range of consistencies. Generally, also, they are translucent, having the consistency of petroleum jelly. They also maintain their consistency to a lower limit of about −40 degrees C.

Properties of the Varnish Type

The two grades of silicones described up to the present have been thermoplastic. Those about to be described, however, are thermosetting, and the valuable applications to which they lend themselves are dependent on this property. The materials are, of course, derived from the resins, which are capable of growing in three dimensions.

The primary advantage of the varnish-type silicone resin is its great thermal stability and resistance to moisture. It also has many other important properties. For instance, it will readily withstand tough service conditions, can readily be used as an impregnant and adhesive, and may be applied as any conventional organic varnish. It is also resistant to oils, chemicals and the like. Electrically the silicones have excellent properties, as is illustrated by Table 2. This applies to most of the silicones (all varieties). In addition to the facts in the table, it may be noted that the silicone varnishes have good track resistance, and that the properties are maintained at high frequencies. Increased temperatures do not greatly increase the values given, and in the case of the liquid silicones it should be noted that although the power factor does increase with temperature, it remains lower than that of a typical transformer oil.

Table 2.—Dielectric Properties of Silicone Resins.

Property	Value
Dielectric constant (20°C.) 60 ~ ..	2.7–2.8
Dielectric constant (20°C.) 10^6 ~ ..	2.8
Power factor 60 ~	0.0001 or less
Power factor 10^7–10^8 ~	0.0001
Power factor 10^8 ~	0.0002–0.0004
Dielectric strength (100 mils)	250–300 V/M.
Volume resistivity ohm/cm. (20°C.)	10^{14}
Volume resistivity (200°C.)	10^{12}

In applying the resins, they should be baked to a tack-free surface. This may usually be accomplished by giving a cure equivalent to two hours at 250 degrees C., or if not convenient about two to four hours at 150 degrees C., followed by two

hours at 200 degrees C. Incidentally, the films may be made flexible.

These varnishes, it has been stated, are used as impregnants. This is because of the ease with which they wet surfaces. They are, therefore, satisfactory for impregnating glass fibres, mica and asbestos, which may be plied up, cured in presses, to form heat-resistant laminates.

The toughness, lightness, electrical properties and thermal stability of the resins allow them to be used in much smaller quantities than most insulants, thus permitting much greater efficiency.

Moulding Silicone Plastics

Moulding powders have not yet appeared upon the market, but it will not be long before they do. Nevertheless, forestalling their actual appearance, some of their properties may be given. Before doing this, however, one or two of the reasons for their being behind the other varieties may be advantageously explained.

The main difficulty is their rate of cure. They are comparatively slow curing, and need high temperatures for fairly long periods. This means, therefore, that they would be expensive, for they would tie up presses for long periods. Preheating methods would be difficult to apply, and it definitely would not be possible to use H.F. methods (due to the lower power factor). Neither do these resins have really distinct A, B and C stages, and it is difficult to make moulding powders in the conventional sense of the term. The best possibility lies in impregnating the various fillers, in the liquid stage, partially curing in the open and then moulding.

So far as properties are concerned, these would be very similar to those of the baked varnishes or laminates. Both the mechanical and electrical properties would be very similar. We should have mouldings which would maintain their properties at really high temperatures. An example of this may be given. For rigid H.F. insulants it is usual to use polystyrene mouldings or possibly styramic H.T. (polydichlorostyrene).

These are quite satisfactory at normal temperatures (up to 70 degrees C.), but above this the power factor, for instance, rapidly increases (apart from the softening). At 90 degrees C. it is about 0.0009, but at the same temperature the value for the silicone plastic is about 0.0001-0.0002.

One final point may be mentioned. There are plenty of high-temperature, inorganic fillers about (mica, slate, glass, etc.), but up to the present there have been no suitable binders which will withstand high temperatures. Bakelite resins are fairly high-temperature resins, but they will not wet the fillers. On the other hand, the alkyd resins are suitable wetting agents, but will not withstand high temperatures. Silicone resins fulfil both the requirements, and will, therefore, find a ready field of application.

Silicone Synthetic Rubber

A new elastomer based on silicones offers the possibility of some very unusual applications. The main features of the rubbers are the high and low temperatures at which they may be operated. The elastic properties are maintained at temperatures (for short periods) up to 220 degrees C., and as low as −40 degrees C. These cannot, of course, be regarded as continuous operating temperatures, which may be looked upon as about 150 degrees C. It is possible to operate for days at a time, however, at 200 degrees C. It should be noted that the top operating temperature of natural and synthetic rubbers is about 80 degrees C. Incidentally, the silicone elastomer is not compatible with the usual elastomers. Properties in general are maintained and the set is low at the extreme conditions.

Other ageing properties are better than those of natural rubber. For instance, ozone, corona effects and ultra-violet light are resisted quite readily.

One of the big drawbacks of the new synthetic rubber at the present time is its very poor tear and tensile strengths. There is no reason, however, by a suitable combination of C, Si, and O atoms, that this should not be improved.

Also of importance is the lack of un-

saturation, and therefore curing possibilities. This does not matter in some instances, but in others it is possible to incorporate double bonds into the formula and some curing properties are conferred. The rubber may be mixed with the usual fillers and milled, extruded, etc., exactly like natural rubber.

Plastic-elastic Silicones

A by-product of the manufacture of the silicone elastomer is a peculiar substance, which feels like putty and may be deformed in exactly the same way, and yet, when dropped on to the floor, bounces like rubber.

This seems to be rather paradoxical, for quite different molecular arrangements are required for elasticity and plasticity. The intermolecular forces must be a border-line case, and the phenomenon is explained by the fact that when the stress is applied slowly (i.e., the putty is pulled apart) it acts as putty, but when the stress is applied rapidly (i.e., bouncing) it acts as though it were elastic.

In common with the other silicone materials, it maintains its properties over a wide range of temperatures.

Applications of Liquid Silicones

Not only are the silicones unusual in themselves, but they have many extraordinary applications (at least so far as plastics are concerned).

The different valuable properties of the liquid silicones may be used separately. For instance, they may be used as liquid dielectrics (oil-filled cables), or, on the other hand, employed as general fluids, which have to be non-volatile at elevated temperatures, maintain a fairly constant viscosity over a wide range of temperatures, and also keep their fluidity at low temperatures (only one of these properties may be needed for any particular application): suggestions are damping fluids and gauge fluids.

The materials may also be used as general impregnants (resistance to chemicals) for asbestos packing and gaskets in chemical pumps.

Many applications will arise from the water-repellent nature. Before describing one or two of these it would be advantageous to mention the best way of applying the water-repellent material. The articles should be first exposed to moisture (preconditioned at a R.H. of 70 per cent.) and then the surface exposed to the vapours of an organo-silicon-halide (a satisfactory example is a methyl chlorosilane[5]). If the surface is then exposed to the atmosphere, any generated hydrochloric acid is dispersed.

Applications are (1) as a general water-repellent; (2) to treat dielectrics so that condensed moisture will collect in drops and not form a conducting path; (3) making paper washable; and (4) treating the inside of liquid gauges so that the level of liquid which has to be read is perfectly flat.

Applications of Grease Silicones

With suitable modifications, the grease-type silicone resins may be used in the same places as the liquid type. There is another very useful application, however, and that is as a lubricant. The temperature at which electric motors operate, for instance, is dependent on (1) the type of insulants, and (2) the type of lubricant. The first will be dealt with later, but the second concerns the silicone greases. These may be used at high temperatures and satisfy a very pressing need.

Another useful application in the lubricant line is as a chemical grease. The inertness makes it very suitable for stop-cock lubricants and the like.

Application of the Varnish Type

The varnish-type synthetic resins probably have potentially greatest possibilities, since really high-temperature insulation is now possible. The old organic insulants soon failed at high temperatures, due first to carbonization, tracking and the formation of conducting paths due to the admission of moisture. The silicones have both high temperature and high moisture resistance.

One of the biggest applications is in connection with electric motors, where the efficiency has almost unbelievably been increased. Inorganic insulation has been

available for some time, but there have only been organic adhesives and impregnants available, which have not allowed the full value of the inorganic insulants to be brought out. For instance, magnetic wire wound with glass can only operate at about 120 degrees C. with ordinary insulants. This temperature may be increased to between 150 and 220 degrees C. when silicone resins are used. So far as electric motors are concerned, this increase in operating temperature is general. The ambient temperature of operation may be increased enormously, and this, it may be noted, under very humid conditions. It is possible for an electric motor, insulated with silicone resins, to operate continually up to about 200 degrees C. and for short periods up to 300 degrees C.

It may be noted that high-temperature lubricants must also be used under these conditions, and the silicone greases are admirable for this purpose.

The silicone varnishes may be used wherever high temperature and high humidity conditions are found. They are used for filling up voids in inorganic insulants, and may, of course, be used for producing instrument boards from laminated materials. They have also been used for insulating tape, and have been tried as impregnants for kraft paper to make condensers.

The resins have many post-war possibilities, including lacquers for all stoves, cookers, refrigerators and the like.

Application of Silicone Mouldings

No current applications of silicone mouldings can be described because there simply are not any. It is not difficult to imagine where such mouldings could be used. One big market would be for export electrical mouldings to tropical countries, where comparatively high temperature and high humidity conditions prevail. Outdoor mouldings, too, of all types, because owing to the highly water-repellent nature of the surface the possibility of the formation of a continuous conducting path would be minimized.

All high temperature applications may also be considered, and it will be left to the reader's imagination to decide all the possible uses in this direction—a problem which should not be difficult.

Applications of Silicone Rubbers

Silicone rubbers have already found extensive applications. This is where shock absorption is required at high temperatures. Two such examples are various gaskets on machines, and searchlights stationed near guns. The first instance may be applied particularly to aircraft, where great extremes of temperature are encountered. In the form of the gasket, the silicone rubber may be compressed to two-thirds of its original dimensions, held in this state for 12 hours at 150 degrees C., and when released springs to 90 per cent. of its former dimensions. Similar considerations apply to the searchlight use.

So far as future applications are concerned, soft rubber or "vulcanites" may be produced. They cannot at the moment be used where high tensile strengths are required, but there are plenty of other possibilities, as, for instance, for hot-melt printing-ink rolls, gloves, hose and the like.

No special section will be devoted to the "bouncing putty," because no applications have been described. We shall have to await developments.

Summary and Conclusions

It is obvious from the above discussion that the silicone plastics and resins have a big future. They are rapidly entering all fields of industry, and some of the older materials will have to be quickly improved, else they will soon be replaced. The materials to manufacture the silicones are very abundant, and there seems to be no reason why they should not be quite cheap.

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of plastic sheets is dealt with by Greene

may be used to fabricate entire air

World's Industry Employs Plastics

GENERAL ENGINEERING

Plastilock 500, a new rubber cement developed by the Goodrich Company, is claimed to possess superior bonding qualities, particularly if used with combined heat and pressure. Metal to metal bonds with a shear strength of 325 lb. per sq. in., and a tensile strength of 4,000 lb. per sq. in. has been obtained. ("Automotive and Aviation Industries," 1945/92/154.) **Railroad engineering can usefully apply plastics,** according to a recent article in "Scientific American," 1945/92/149. The account outlines the use of these materials in lighting fixtures, upholstery, draperies, structural components and electrical fittings. **Burned out fluorescent light tubes** are salvaged at the Glenn L. Martin Company to serve as moulds, plastic rods, to be used as tool handles, stiffeners, etc. One end of the tube is cut off the body, being then filled with a liquid thermosetting resin (Catabond or Catavar), the whole being then covered in an oven. Afterwards the glass is broken away, leaving a virtually polished plastic bar. ("Automotive and Aviation Industries," 1945/92/39.) **Perforated boiler plate in blast cabinets is protected by Compar sheets.** The abrasion resistance of this rubber-like plastic is said to be about 250 times that of steel. **General properties and uses of moulded plastics** are summarized in a data sheet by Bois, reproduced in "Machine Design," 1945/17/171. Over 40 different materials are listed. **Metlbond adhesives for metals** are fully discussed by Harens and Jenks in a recent issue of "Iron Age." Metlbond adhesives consist of a combination of synthetic rubber and a plastic. **A survey of recent developments in synthetics** used in engineering is given by Black in "Mechanical Engineering," 1945/67/267. The review includes mention of synthetic substitutes for natural rubber, and refers to glass-reinforced and woven-plastic fabrics, modern finishing materials, impregnating materials for porous castings, stripping lacquers, resins in highway construction, silicones, foamed rubbers and flame sprayed rubber, etc. The paper includes a bibliography of 220 items. **New design ejector pins for plastic moulding components** are described by Wessel in "The Machinist," 1945/88/219. Close-fitting and well-aligned ejector pins are required for thermoplastic moulds. This is required in order that they may be kept free of moulding material, so eliminating binding and premature breakage. **Plastics for structural and non-structural purposes** are discussed by Hoeltzel in "Automotive and Aviation Industries," 1945/92/38. The author considers all the more recent developments in this field. **Under the name "Ameritred" a new-type material has been evolved to replace normal rubber matting.** The material consists of aggregates with high coefficients of friction bonded with a plastic to give a firm, solid mass, jet black in colour. ("Textile World," April, 1945. **Drain-off units for sinks** fabricated by screwing together of three components all made of cellulose acetate are manufactured by A. G. Tomkins Co. ("Product Engineering," 1944/15/737.) **Constant-volume-flow injection moulding machines,** suitable for use with thermoplastic and thermosetting resins, as well as rubber, have been designed by Cousino of the Chrysler Corporation. A full account of this plant is given in "Product Engineering," 1944/15/738. **Vacuum forming** as a technique in the fabrication

of plastic sheets is dealt with by Greene in "Product Engineering," 1944/15/731. Acrylic sheets are formed by this process into turrets and other parts for aircraft. In particular, the author deals with "spring-back." **Transparent models** are utilized to study the flow of lubrication through a bearing. By tinting the oil supplied by a circulating pump, problems of turbidity, etc., may be more readily studied. ("Machine Design," 1944/16/79.) **Review of post-war uses of plated plastics** is given by Brams in "Iron Age" for February, 1945, Vol. 155, p. 62.

AIRCRAFT

Modified butadiene-styrene-type synthetic rubber latex has been evolved by the United States Rubber Co., which is claimed to possess excellent saturating properties for paper and fabrics as required in the manufacture of artificial leathers, and is claimed as an excellent binder for vegetable fibre and animal hair employed in the cushioning mass for combat tanks, parachute seats and aircraft upholstery. ("Automotive and Aviation Industries," 1945/92/86.) **Hand-operated emergency pumps for inflating life rafts** in case of failure or loss of the conventional cylinder of carbon dioxide, are furnished with a phenolic resin-impregnated paper barrel, the connecting coil being in Tenite II. ("Scientific American," 1945/92/152.) **New plastic laminate "Conolite"** is produced by impregnating glass fibre and fabric with a new type of thermosetting resin. Immersion in salt water for periods of 24 to 48 hours produces no harmful effect. This laminate is peculiarly free from resonance effects, and actually has a high damping capacity for vibration. Its tensile strength may be as high as 55 tons to the square inch, whilst its specific gravity is 1.64; from the standpoint, therefore, of plastic strength it is superior to duralumin and comparable with steel. Eventually, it is claimed, it may be used to fabricate entire air frames. ("Machinery," New York, 1945/51/220.)

CHEMICAL

Melamine-type-resin ion-exchange bases have been developed by the American Cyanamid Co. One resin bed removes dissolved salts, another removes any acids which may be present. The output water is equivalent in ion content to conductivity water. ("Chemical and Metallurgical Engineering," March, 1945.) **Silicon resins** produced by General Electric Co. can be utilized for the production of heat-resistant white coatings; these will not discolour after exposure for hundreds of hours to temperatures up to 250 degrees F. Furthermore, they are resistant to water, acids and alkalis. ("Chem. and Met. Engineering," December, 1944.)

ELECTRICAL

Insulation and protection of cables passing through bulkheads of ships and aeroplanes, as well as for other purposes of electric insulation, is simplified by the development of the two-piece "Des-Grommet" in Lumarith. The parts may be applied from one side only, a special tool being used for insertion. ("Machine Tool Blue Book," 1945, April/41/300). **Glass-base plastics are now available in sheet form.** In one case a fine-weave continuous-filament glass-fibre fabric is impregnated with Melamine resin; the resulting material is said to be more resistant to flame and to arcing than the resins commonly used in laminates, and possesses valuable electrical applications where fire resistance is of paramount importance.

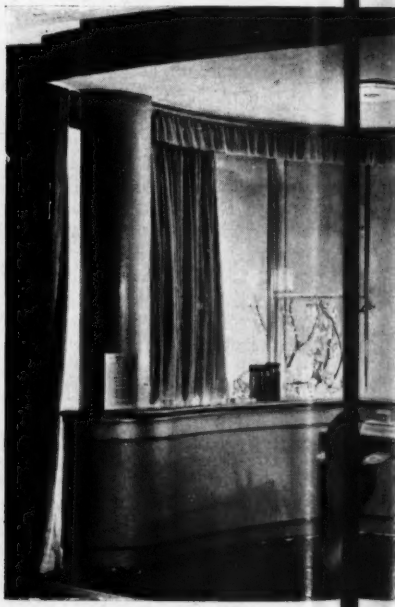
METAL and PLASTICS

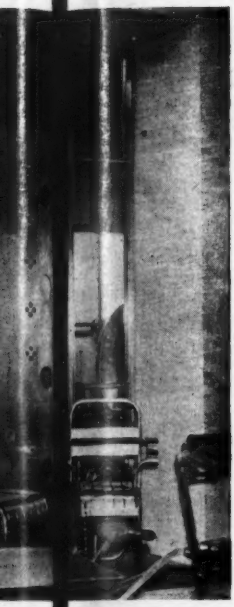
Combine in Beauty

ALL roads, it would seem this month, lead to Selfridge's, where an Aluminium Exhibition is being held. We believe that workers in our own industry would be well repaid by a visit to examine this collective effort in an objective manner. This "Cinderella" of metals has indeed advanced.

The aluminium industry is, it is true, in a much more fortunate position than the plastics industry, in that its thoughts can dwell more closely on peace-time production: much less of the metal is being employed for warlike purposes and the plant for production of much of its finished goods, especially for consumption in the home, is ready to hand without much change. In addition, there has also been, at least for the purposes of this show, an amazing unity and co-operation of interests between the aluminium manufacturing concerns to create an exhibition of an industry and not of individual competing firms that is as pleasantly surprising as it is praiseworthy. This is reflected in the speed with which the exhibition has been completed and in the beauty and dignity of the results.

Of special note is the tribute paid to plastics by inclusion in some of the exhibits. It is true that only one type, methyl



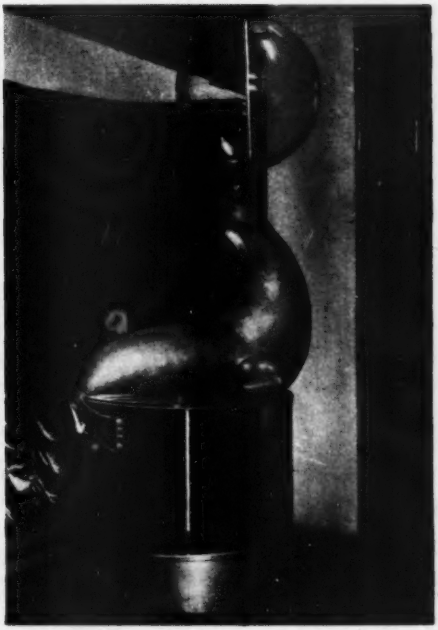


The Aluminium Exhibition at Selfridge's, Which Began on May 30, Will be Open to the Public Until June 30

methacrylate sheet, has been used, but this is readily explained by the fact that this material can be simply and easily worked.

The absence of other plastics need not worry us unduly, nor need we be at all critical of the use of " Perspex " in every instance. Without doubt, the designers wish to impart the essential idea of flexibility of thought in construction by purely æsthetic means.

The central picture shows a curved bay window with desk and chairs in the foreground. The windows are of " Perspex," the dyed and anodized aluminium desk is covered with a large sheet of the plastic, which is also used as armrests on the chair. The sliding door is machined from a massive slab of aluminium, the " windows " being formed by boring and pressing in turned " Perspex " lights. The statuette was designed for casting in aluminium by J. Woodford, R.A. The figure holds a " Perspex " ball, whilst on the faces of the base upon which it stands is a series of plaques engraved in " Perspex " and depicting the arts and sciences in which aluminium finds applications. The aluminium seal with globe blown from " Perspex " has been designed by R. Lavers.



Radio Wiring Insulation

An Analysis of Types Available for Tropical Use

By W. J. TUCKER and J. V. WREDDEN, F.R.M.S.

THE article on tropic-proof wiring for radio equipment, which appeared in the February issue of "Plastics," attracted widespread interest, and there have been many requests for more information on the subject.

In this article the requirements are analysed in greater detail, and the results of specific tests are given.

The requirements, as stated in the previous article, are adequate dielectric strength, high resistance to moisture absorption, stability in varying service conditions, such as exposure to extremes of temperature and high humidity, mechanical strength to a degree sufficient to resist the destructive effect of flexing and abrasion, and chemical inertness.

Adequate dielectric strength is a loose term, and obviously the degree of strength obtained will depend on the thickness of the wire covering.

The breakdown strength of popular sleeving materials is given in Table 1.

The margin of safety is so ample for normal low-power radio applications that the only real risk of breakdown arises when the insulation properties of the sleeving are completely ruined by disintegration or prolonged exposure to unfavourable conditions.

From the radio engineer's point of view the volume and surface resistivity characteristics of a sleeving material are as important as its strength to resist actual breakdown.

The dielectric constant of an insulating material becomes an important factor when that material is used in high-frequency alternating-current circuits. Intercapacity effects between adjacent conductors are taken into account when the apparatus is designed, but in the event of the dielectric constant of the insulator becoming a variable factor, efficiency is impaired and the circuit becomes unstable. Where conductors are run in sleeving, and adjacent to one another, the sleeving acts as a dielectric separating two plates of a condenser. At high frequencies the small capacity which exists between these two conductors may have a considerable bearing on the performance of the equipment. Hence it is essential that this capacity remains constant, so that allowances can be made in the general design. If the dielectric constant varies in relation to service conditions the capacity will also vary, and the degree of variation will be uncontrollable.

Adverse changes in all the electrical characteristics are brought about by the

Table 1.

Sleeving material	Breakdown strength at 20°C.	†Usual wall thickness	Specification tests
Polyvinyl chloride	300–500 volts/mil.*	0.6 to 0.8 mm.	First quality: 3,000 volts R.M.S. at 100/120 cycles for 10 minutes. (This test to be applied twice, before and after flexing test.) Second quality: 1,500 volts 100/120 cycles for 10 minutes. Third quality: 1,500 volts 50 cycles for 1 minute.
Rubber	600–700 volts/mil.	0.6 to 0.8 mm.	
Polythene	1,000 volts/mil.	0.6 to 0.8 mm.	
Rolled varnished fabric ..	300–500 volts/mil.	0.5 to 0.8 mm.	
Varnished fabric	300–500 volts/mil.	0.4 to 0.8 mm.	

* Mil. = 0.001 in.

† Wall thickness is adjusted according to diameter or internal bore of sleeving. P.V.C. sleeves are usually made thicker than other types to counteract tendency of P.V.C. to split when heated by soldering operations. Nevertheless, P.V.C. can be made so accurately, and extruded on the wire, that overall diameter of insulated conductor is usually less than with other sleeving materials.

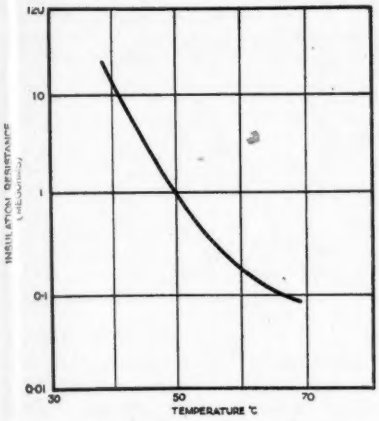


Fig. 1.—Effect of temperature rise on resistivity of P.V.C.

presence of moisture in or on the surface of insulating materials. Breakdown strength is considerably reduced, volume and surface resistivity is lowered, and the dielectric constant becomes a variable factor. It follows, therefore, that when service in damp atmospheres is contemplated, the electrical efficiency of the insulating material used for making sleeving or wire covering must be considered in relation to the moisture-repellant properties of that material.

The volume resistivity of the varnished cellulose types of sleeving is better in dry atmospheres than that of polyvinyl chloride, and as the temperature increases the resistivity figure for P.V.C. falls (see Fig. 1), but the drop which occurs is not comparable with that which takes place when cellulose types are saturated with water, and therefore in humid atmospheres polyvinyl chloride is still superior to the cellulose products.

Since insulation efficiency depends so much on the moisture-repellant properties of a material, we will examine the results of a test carried out on 39 different samples, representative of the following six varieties of sleeving:—

1. Varnished cotton, consisting of a tubular cotton braid treated with a linseed-oil varnish.

2. Varnished silk, being tubular silk braid treated with a linseed-oil varnish.

3. Braided oiled silk, consisting of a tube of oiled silk, made by rolling, which is covered externally by a tubular cotton or silk braid.

4. Polyvinyl acetate on silk. This consists of a tubular silk braid treated with a solution of P.V.A. in the same manner as the varnished cotton.

5. Polyvinyl chloride, consisting of a simple tube of extruded P.V.C. carrying suitable pigments and plasticizers.

6. Braided P.V.C. This is a modification of (5). The P.V.C. is covered externally by a tube of either silk or cotton.

The test was carried out by the conventional gravimetric methods, and consisted of weighing a 2-in. length of the sample before and after immersion in distilled water for 24 hours, the moisture absorption being expressed as a percentage of the weight of the dry sample.

The results of this test, which are given in Table 2, indicate that all the varnished cotton sleevings and others which contain a cellulosic fibrous base offer a very poor resistance to the penetration of moisture.

The high figure for varnished silk is probably due to the capillary effect of the continuous silk fibre, as compared with that of the short cotton fibre.

A comparison of the figures given for samples 5 and 6 prove conclusively that the presence of fabric automatically leads to a high intake of moisture, and since all the cellulosic samples were varnished, the figures quoted also provide evidence that,

Table 2.—Moisture Absorption of Sleevings, 24 Hours' Immersion. Percentage Increase in Weight.

Sample	Moisture absorption (average of three samples)
1a	4.226
1b	2.016
1c	9.76
1d	3.88
2	18.5
3a	6.93
3b	5.35
3c	7.26
3d	6.32
4a	10.64
4b	9.87
5	0.26
6	2.57

Table 3.—Effect of Heat Ageing on Various Samples of Sleeving Material.

Type	Effect of heat ageing
1a	The varnish turns brown and discolours, pigments being destroyed or altered. After the tubing had been bent twice through 180° the wall of the tube splits and the fabric ruptures. One bend was sufficient to crack the external varnish coat.
1b	The varnish browns and discolours, the whole tube becoming very brittle and breaking immediately any attempt to bend it is made.
1c	The varnish browns and discolours, but the flexibility is much better than 1a and 1b. The external varnish coat breaks only after eight to ten bends through 180°.
1d	Colour appears to be stable, with the exception of red, which is fugitive and becomes a deep chocolate brown. The tube retains its flexibility well and is comparable with 1c in this respect.
2	The varnish discolours to a deep brown, but flexibility is well maintained. This again being similar to 1c.
3a	The inner roll of silk becomes brittle and cracks after two bends. The external braid remains unchanged both in mechanical properties and colour retention.
3b	Much the same as 3a, but the red dye used on the braid is fugitive.
3c	The silk appears to be better in this case, retaining about 80% of its original flexibility. Red dye is partly fugitive.
3d	Similar to 3c, but the silk is slightly less flexible.
4a	The plastic medium (P.V.A.) softens considerably and is subject to slight plastic flow; this gradually decreases as the plasticizer is extracted and eventually becomes very hard and black, being extremely brittle.
4b	As this tube is the same type as 4a, precisely the same effects were expected and obtained.
5	In this case the tube is unaffected after cooling, although it does become somewhat harder, the toughness and flexibility are slightly improved. The tube is soft and very flexible while hot.
6	This sample is similar to 5, the braid is unaffected and dyes appear to be stable.

in all cases, the textile base has not been completely impregnated.

Effect of Exposure to Heat

Comprehensive tests were made on a similar selection of samples with the object of determining the effect of exposure to heat on the various types of sleeving material.

The results obtained are given in Table 3.

The reason for making these tests at 150 degrees C. was that for some applications, such as transformer manufacture, it is not possible to keep the temperature within the limits usually specified as desirable for polyvinyl chloride, and it is as well to know how this material compares with the others when subjected to a temperature as high as any likely to be encountered anywhere in a radio equipment.

Potential users can judge for themselves by reference to Table 3 to what degree it is justifiable to rule P.V.C. out for moderately high temperature applications in favour of using materials which are lacking in other respects.

It is noted that polyvinyl acetate lost its flexibility, but polyvinyl chloride retained this quality. No tendency to disintegrate was noted with the latter material.

Table 4.

Sample	pH of aqueous extract
1a	5.0
1b	4.75
1c	4.4
1d	4.4
2	4.4
3a	4.4
3b	4.85
3c	4.4
3d	4.8
4a	7
4b	7
5	7.5
6	7.5

Table 5.—Effect of Solvents on Sleeving Materials.

Sample	Formaldehyde	Toluene	Alcohol	Acetone	Petroleum ether	Benzene	Phenol	Xylol
1a	C	G	G	G	A	G	G	G
1b	C	G	G	G	A	G	G	G
1c	C	G	G	G	A	G	G	G
1d	C	G	G	G	A	G	G	G
2	D	G	G	G	A	G	G	G
3a	C	G	G	G	A	G	G	G
3b	C	G	G	G	A	G	G	G
3c	C	G	G	G	A	G	G	G
3d	C	G	G	G	A	G	G	G
4a	E	G	F	G	A	E	G	G
4b	E	G	F	G	A	E	G	G
5	A	A	A	C	A	B	B	A
6	A	A	A	C	A	B	B	A

Key to table: A, no effect; B, very slight attack; C, slight attack (softens to a gel); D, moderately attacked; E, fairly heavy attack; F, heavy attack; G, very heavy attack (disintegration or solution).

Acidity (pH) of Aqueous Extract

This test was carried out to compare the chemical inertness of the various sleevings, and from the results given in Table 4 it will be seen that the only acid-free materials are the synthetic ones; 4a, 4b, 5 and 5b are neutral, whereas all the others are very acid. This acidity can be attributed to the varnish, the acid being liberated and put into active form in the presence of traces of moisture. Obviously the formation of these acids will be accelerated in humid atmospheres.

Solvent Resistance

This property is not important in general radio wiring, but must be taken into consideration when providing insulation for use in the presence of impregnating varnishes, such as are used for treating transformers and coils.

Tests were, therefore, carried out with the results shown in Table 5.

From the figures quoted, and the detailed consideration of the requirements which has been given, it is obvious that plastic sleevings of the polyvinyl chloride type are far more suitable for use in tropical and sub-tropical climates than the cellulosic sleevings previously used.

The authors wish to acknowledge the assistance given to them by Messrs. Igranic Electric Co., and in particular by Mr. R. K. Fleming, in supplying the facilities for carrying out the tests and for permission to publish the results.

Tropic-proof Wiring for Radio Equipment

Sir,—Mr. Walter J. Tucker's article in your February, 1945, issue has just been brought to our notice.

Mr. Tucker's enthusiasm for the plastic cause appears to have led him into the condemnation of all impregnated textile sleevings, which is unjustified. It is true that he does not mention silk or rayon sleeving, but the implications in his article would seem to apply.

As the inventors of "Symite" and originators of rolled varnished silk high-tension sleeving for tropical use, we wish to refute this. Such sleeving properly made from suitably treated silk has been proved for many years to withstand all the variable conditions of high humidity, with rapid changes of temperature generally described as "tropical," and our record of supplies to the Crown Agents for the Colonies and other users, for many years, will amply bear this out.

The large gaps between sleeving and wire, which Mr. Tucker states generally exist when fabric sleeving is used, do not apply to our rolled silk sleeving, which compares favourably with any thermoplastic extruded product for accuracy of dimensions. The statement that P.V.C. will stand up better to bending does not always apply. A mechanical bend test carried out on copper flexible covered with our sleeving resulted in the wire breaking, while the sleeving remained a good insulator.

The fact is, as Mr. Tucker states, that P.V.C. can only compete with fabric sleeving under really severe conditions when reinforced with fabric!

We put forward these points in favour of our own product, in the full knowledge that P.V.C. undoubtedly has its uses, and may be preferred in many instances to a rolled silk fabric, but the converse is equally true. P.V.C., after all, depends entirely for its flexibility upon a plasticizer of some sort, the result being merely a mixture of two substances, quite unlike the stable product which is produced by the stoving and complete chemical change of a suitable insulating varnish. The question of suitability for use near soldered joints, and the fact that P.V.C. cannot be used on leads from coils subject to impregnation and stoving, need not be stressed.

H. D. SYMONS AND CO., LTD.
Kingston Hill, Surrey.

[Editor's note: We have forwarded a copy of this letter to Mr. Tucker, who replies that he hopes the preceding article will support his contentions.]

Hot-spray Method of Coating Paper with Plastic Material

By N. N. MURTY

THE use of shellac bond in the production of laminated boards and tubes is well known, the shellac-coated paper being particularly suitable for very high-voltage bushings. The method of coating paper with shellac hitherto has been to pass the paper through shellac varnish or to use the glue-spreader technique, the treated paper then being passed through an oven to effect evaporation of the solvent. The industrial spirit used for this purpose is expensive and inflammable, and attempts to replace this with alkaline solvents like ammonia, ethylene diamine or triethanolamine have not met with great success.

The hot-spray method avoids the use of solvents altogether as it consists in passing powdered resin at high velocity through the flame of a gun, the molten or plastic particles emerging from the flame being deposited as a film of resin on any material held in front of the flame. Factors familiar to the plastics industry, such as thermo-softening and pressure, are involved in the particles assuming a flat shape and welding together to produce a continuous film. It may, at first sight, appear that greater fire risks are involved in treating paper by this method than by the solvent process. In reality, however, with careful design of machinery, the risks are practically non-existent, the paper not even showing signs of scorching.

The experimental machine in its present form is illustrated in Fig. 1; Fig. 2 shows a sectional view of the machine and, together with the attached key, is self-

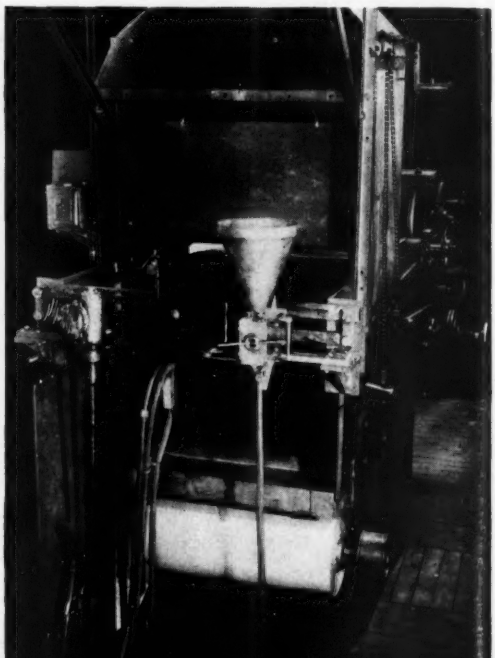


Fig. 1.—Experimental spraying machine.

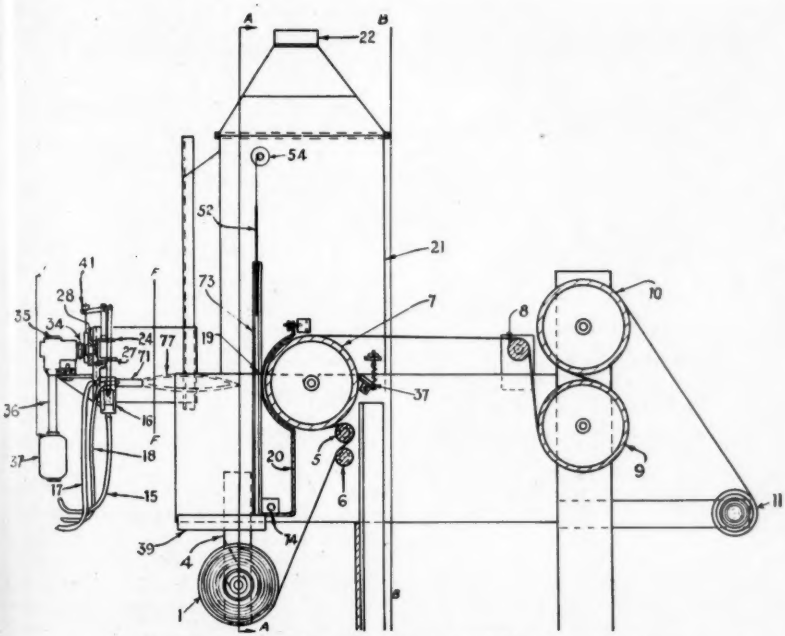
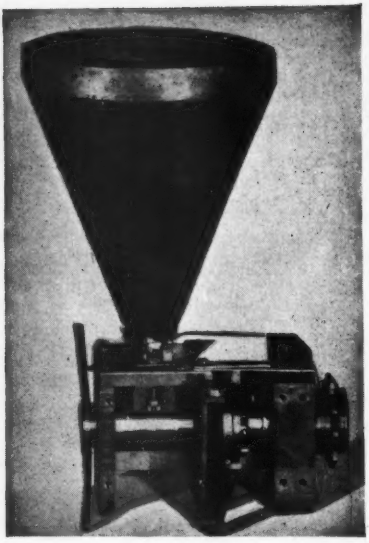


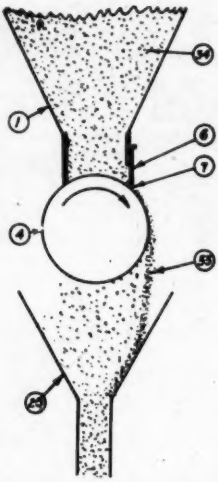
Fig. 2.—Side sectional view of the hot-spray machine for coating paper.

1.—Roll of paper on mandrel. 5, 6, 8.—Guide roller. 7.—Spray roller (positively driven). 9, 10.—Draw rollers (positively driven). 11.—Winding roller for treated paper (friction clutch drive). 16.—Hot-spray gun. 15.—Powder feed line. 17.—Compressed air feed line. 18.—Gas feed line. 71.—Barrel of gun. 77.—Flame. 19.—Slit in guard plate (20). 52.—Drop door suspended from mandrel (54). 73.—Slotted guide bars for drop door (52). 74.—Swivel mounting for guard plate. 37.—Spring-loaded overspray scraper. 39.—Tray for receiving unsprayed and recovered shellac. 21.—Hood for extracting fumes and hot gases through duct (22). 35.—Reduction gear connected to gun feed sprocket (34). 36.—Flexible shaft driven by motor (37). 28, 29.—Guide bars for reciprocating gun carriage. 24.—Bracket projecting from gun carriage. 27.—Bracket of gun adjustably attached to lower arm of bracket (24). 41.—Plunger device operating slide door on powder feed duct in gun.

explanatory. The design of a machine such as this involves, as in the case of all machine tools, co-ordination and control of the various feeds.

The success of depositing a uniformly thick coat of resin on paper is very much dependent upon the maintenance of an uninterrupted steady stream of powder to the gun, a condition which is particularly difficult to achieve in the case of light resinous powders containing excess of "fines." After trying out various feed methods, a mechanical powder-feeder was specially designed to operate in conjunction with the hot-spray machine which has ensured the necessary regularity and control in the feeding of powder. Fig. 3 and Fig. 4 illustrate the principle and constructional features of this unit. In the centre of Fig. 1 will be seen the powder feed unit mounted in position on the hot-spray machine. The powder contained in the hopper is drawn off through an adjustable gate by the revolving drum and is then transported to the barrel of the gun from the collecting funnel on the injector principle. The passage of particles through the flame is so quick (initial velocity of 100 m.p.h. at 40 p.s.i. of compressed air) that hardly any burning of the shellac particles takes place, provided particles finer than 120 mesh are excluded. Very coarse particles become insufficiently plastic to stick to





Figs. 3 and 4.—Feed hopper and control.

1.—Hopper. 4.—Feed drum. 34.—Powder. 6.—Adjustable gate. 7.—Gate opening. 33.—Powder stream. 25.—Collecting funnel.

paper and drop down to the collecting tray. The cost efficiency of the hot-spray method, therefore, is dependent in some degree on the extent to which the powder is free from coarse and fine particles. As an example, orange shellac powder, 80 per cent. of which is composed of particles lying between mesh sizes 80-120, can be sprayed with less than 8 per cent. overall loss under optimum spraying conditions. Microscopic examination indicates that the burnt shellac does not reach the paper but is drawn off by the flue along with hot gases. This is further corroborated in the electrical data recorded in Table 1.

Recovery and re-use of shellac deposited beyond the edges of the paper due to overshoot of the gun at either extremity of reciprocation can be effected by using side masks with a water curtain arrangement. Alternatively, the stroke or span of the gun traverse can be adjusted to lie within the width of the paper, and by means of the plunger mechanism (Figs. 1 and 2) designed to operate automatically a valve in the powder feed line, the powder supply can be shut off at the extremities of the gun traverse. Adjustment of the stroke is accomplished by altering the chain length and position of the sprockets, the flexible shaft drive permitting such adjustments.

The chain method of obtaining uniform feed motion of the gun across the paper is better suited for papers wider than 12 ins., whilst for strips of short width the cam method of feeding the gun is suitable. Better economy results, however in treating a paper 40 ins. wide and slitting the coated paper to any desired width.

The gun used in conjunction with the machine is an adaptation of the simplified form of hot-spray gun developed by Lalkaka (Bulletin No. 5 of the London Shellac Research Bureau, 1939), which operates in a similar manner to the powder metal spray pistol, but does away with the use of oxygen and special fuels like acetylene or propane, which are not required in the case of most plastic materials.

The spray of molten or plastic shellac passing through the flame of the gun reaches the paper through a slit in the guard metal sheet. The distance between the tip of the flame and the paper is

Table 1.—Data Relating to the Hot-spray Method of Coating Paper with the Help of the Experimental Machine.

1. Area of the discharge end of gun barrel	12 sq. mm. ($\sim \frac{1}{50}$ sq. in.)
2. Maximum rate of shellac sprayed through the above gun	3 lb./hr.
3 Velocity of powder at 1 in. from discharge end of barrel at 40 p.s.i. of compressed air	56 metres sec. (~147 ft./sec.)
4. Maximum temperature of flame when spraying	1,200°C
5. Maximum temperature of flame with powder supply cut off	1,450°C.
6. Length of flame at above rate of spray	8 ins.–9 ins.
7. Distance between discharge end of barrel and sprayed material	11 ins.–14 ins.
8. Average temperature of flame along axis of flame	800°C.
9. Fuel consumption (Town gas) per lb. of shellac sprayed	~20 cubic ft.
10. Compressed air consumed at 40 p.s.i. per lb. of shellac sprayed	~20 cubic ft. of free air
11. Electricity consumed ($\frac{1}{2}$ h.p. and $\frac{1}{4}$ h.p. motors) per lb. of shellac sprayed	~0.18 units
12. Consistency of orange shellac powder used	90% lies between 80–150 mesh
13. Speed of coating paper at rate of 86 gm./sq. metre (3 mil. thickness of film)	14 sq.metres/hr. (155 sq. ft./hr.)
14. Speed of coating paper at rate of 50 gm./sq. metre (1.75 mil. thick film)	24 sq. metres/hr. (266 sq. ft./hr.)
15. Loss through burning + unrecoverable waste	~10%
16. B.D.V. (step test at 90°C.) of laminated tube 0.125 in. wall thickness wound from hot-spray shellac coated press paper	60kV., (480 V./mil.)
17. S.I.C. of above tube at 90°C.	4.5
18. Power factor (tan δ) of above tube at 90°C.	0.08

adjusted to between 2 ins.-4 ins. It is essential for the paper to be in perfect contact with the metal surface of the spray roller at the spraying point, in order to avoid scorching, burning or blistering of the paper. To overcome splitting or tearing of weak papers, the spray roller is driven positively at the same surface speed as the draw rollers. In other respects, the familar method of feeding the paper has been employed.

In order to enable cut lengths of sheet material or boards to be given a uniform coating, certain additional features have been added to the experimental hot-spray machine. The sheets or boards are fixed to the drop door (in front of the spray roller), suspended by means of ropes from an overhead mandrel, which can be wound at any required speed by connecting it to the driving gear of the spray roller (on the right-hand side in Fig. 2). In actual practice, however, it may be found desirable to limit the function of the machine to the performance of a specific task rather than adapt it for a variety of jobs.

The chief application of the machine will be in the hot-spray coating of paper intended for the production of laminated boards and tubes. Table 1 gives some data relating to the hot-spray coating of paper with the help of the experimental machine. It will be seen from this table that with the present size of gun a 3-mm. thick coat of shellac can be sprayed at 155 sq. ft. per hour. It is, however, sufficient for the fabrication of laminated boards and tubes to deposit about 50 g. of shellac bond per sq. metre (1.47 oz./sq. yd.) of paper, and, furthermore, by doubling the size of the gun and employing two guns, the above speed can be stepped up seven times. This would correspond to coating 40-in. width paper at a rate of 325 ft. per hour and, it should be stressed, this rate of treatment is achieved by a compact machine which occupies but a fraction of the space taken up by a machine having the same production rate employing solvent methods. The first cost of the machine is expected to be less than that of a machine for treating paper by conventional methods. Frequent attention to the machine can be minimized by adding cylinder capacity to the feed hopper and automatic signals and alarm devices can readily be fitted to interrupt faulty operation. Even without these automatic controls, one operator can attend to two or more machines.

Regarding running cost, it has been estimated that the hot-spray method would prove only half as expensive as the solvent method. The cost of treatment by either method is not, however,

very material compared with the price of shellac.

Briefiy, it may be stated that where continuous thin films free from pinholes are needed, as, for instance. in the coating of metal sheets, the solvent method is to be preferred, although with further development of plasticized shellac powders for hot-spraying there would be advantages in using the new method in this field, too. For the purpose of coating paper for fabrication of laminated products, the hot-spray method offers definite advantages. Since the hot-spray coat does not penetrate into the base material but remains on the surface, it permits pre- or post-treatment of the base material with another dielectric which may be employed for improving the electrical or thermal properties of the laminate. Furthermore, mixed resins or a mixture of fillers and resins can be sprayed which would be difficult to apply by solvent methods owing to factors such as compatibility, common solvents and settling exercising decisive limitations. Any continuous web of material other than paper, e.g., glass cloth, asbestos paper or cloth, linen or jute fabric, can be given a surface coat of plastic material or fusible bond for consolidating the treated material into laminated products. Similar advantages result in the hot-spray coating of absorbent materials such as asbestos, fuller board or wood ply with fusible bond, the possibility of glue-starved joints being eliminated.

Patents have been applied for concerning important features of the hot-spray machine.

The work described in this article has been carried out by the author in the Research Laboratories of Messrs. Metropolitan-Vickers Electrical Co., Ltd., Manchester, under the scheme of co-operative research on the uses of lac in the electrical industry sponsored by the Indian Lac Cess Committee. The author wishes to express his grateful thanks to Mr. A. R. Dunton, of the Materials and Process Section, Research Department, for his continued interest during the development work and for the help given in preparing this paper for publication. Thanks are also due to Sir A. P. M. Fleming, Director of Research and Education, Metropolitan-Vickers Electrical Co., Ltd., and to Dr. B. S. Gidvani, Acting Director, London Shellac Research Bureau, for permission to publish this article.

LETTER TO THE EDITOR

Plastics Study Group

You will probably be interested to learn that a "Plastics Study Group" has recently been formed in the Middle East, with the object of providing means whereby interested personnel of his Britannic Majesty's Forces can study and discuss the present and future fabrication and application of Plastics.

At the moment only two meetings have been held, but good progress has been made in arranging for future lectures and discussions, and it is hoped to increase the regularity of meetings.

One important aspect to the Group should be the formation of a library, and difficulty in that connection is being met due to the scarcity of available publications out here. It occurred to me that a suitable notice appearing in your publication may induce manufacturers to forward copies of brochures and pamphlets which could be placed in the Reading Rooms of the Group, and possibly some readers may be willing to relinquish some old copies of Plastics textbooks which they no longer require but which would be "manna from heaven" to the boys out here.

If you are interested in this venture of ours, I would be pleased to write you a synopsis of, say, one or two months' activities. You will have realized, of course, that one of the main objects of the Group is to prepare, in however small a measure, those people interested for post-war participation in the industry.

CAPT. A. HALLAM, R.A.O.C.,
Secretary, Plastics Study Group.
C.O.P.O. (M.E.), M.E.F.

PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

CHLORINATED RUBBER.—Supply of rubber constitutes a primary problem of the war, and it is now generally realized that, apart from tyres, one of the most vital and highest priority uses is the preparation of chlorinated rubber.

In this field the pioneers in Great Britain are Detel Products, Ltd., of Greenford (near London), who make chlorinated rubber by a special process and supply it dissolved in an organic solvent, being the invention of F. C. Dyche-Teague, the technical director of the company. Essentially, the great value of Detel, especially for the chemical and allied industries, is that it forms, by painting on almost any surface, a tenacious, non-porous film, which possesses remarkable powers of resistance to all kinds of corrosive and deleterious influences. These are so numerous, it is impossible, for lack of space, to give a list, but included are almost every known acid or alkali, dilute or concentrated, and nearly all solutions of inorganic and organic substances in water, as well as oils and sea-water.

Apart from special modifications, such as sheeting, the material, which also may be mixed with pigment for colouring, and with finely divided zinc for use on steel, is applied by means of a brush like paint, the organic solvent evaporating and leaving the film. A wide range of surfaces also can be protected, including iron, steel, metal generally, brick, stone, artificial stone, wood, asbestos, asbestos cement, paper, millboard, leather, artificial leather and fabrics, porosity of the material making no difference.

One of the most important applications is for the treatment of concrete, for which the product possesses peculiar advantages, since the lime in the concrete has no action, whilst the liquid does not penetrate to any extent, so that the hard and extremely resistant adhesive enamel-like film remains on the surface, filling the pores and any tiny holes, cracks and crevices. For this reason the product is valuable for the dustproofing of floors, forming a smooth surface easily kept clean with soap and water, whilst any worn patches are repaired at once merely by painting over. The same applies to concrete walls, benches and tanks.

Some important general applications, in addition, are in the chemical, enamelling, and electro-plating industries, and, further, in connection with garages, oil and petrol have no deleterious effect. Another application is the easy waterproofing of concrete, especially when below the ground level, as in A.R.P. shelters and for sump and tank work, whilst at the same time acting as a paint, which may be very light-coloured, white, cream, or grey. Protection of concrete tanks, pumps, and similar equipment used for acid and other corrosive solutions is another obvious application. This also applies, incidentally, to petrol pumps and to treatment of roofs and walls, whether of concrete or otherwise, as well as pipes, bearings and girders, exposed to a hot, steamy atmosphere, with almost constant condensation, providing the ideal conditions for corrosion.

Due to the present rubber shortage and to the heavy demand for essential war purposes, chlorinated rubber in general, and Detel in particular, is not readily available at present except for work of the highest priority.

DISTRENE.—B.X. Plastics, Ltd., has compiled one of the most attractive pamphlets we have yet seen. It deals with the polystyrene known under the trade-name of "Distrene," made by British Resin Products, Ltd. B.X. Plastics, Ltd., act as sole distributors. This plastic is not only one of the most attractive of all for injection moulding from a technical point of view, but is also one of the most æsthetically beautiful. There are many lovely photographs to entice the reader to closer perusal of the script which describes its manufacture and its manifold uses. Excellent tables of properties are given for use by those industrialists who are not yet acquainted with Distrene. The designers of the pamphlet deserve high commendation.

CONTROL OF PLASTICS.—The Minister of Supply has made the Control of Plastics (No. 3) (Revocation) Order, 1945, revoking the Control of Plastics (No. 1) Order, 1940, and the Control of Plastics (No. 2) Order, 1941.

Licences are no longer necessary for the acquisition, disposal, treatment, use and consumption of plastics in the form of moulding powder, in the production of which formaldehyde, phenol, cresol, urea, thiourea and cellulose acetate are involved, or synthetic resins in which formaldehyde, cresol, phenol, urea or thiourea has been used. Use of cellulose acetate moulding powders, however, must still be restricted and under arrangements with the producers releases for the time being will be on substantially the same basis as hitherto.

For the present there will be no change in the existing method of voluntary control of other types of plastics or of plasticizers.

Copies of the Order may be obtained from H.M. Stationery Office, York House, Kingsway, W.C.2, or through any bookseller, price 1d. (S.R. and O., 1945, No. 539.)

BRITISH PLASTICS FEDERATION.—At the meeting of the Council of the British Plastics Federation, Ltd., held on May 16, Mr. H. W. Graesser-Thomas (Yorkshire Tar Distillers, Ltd.) was re-elected Chairman of the Council and of the Federation for the year 1945-46.

Dr. W. J. Worboys (Imperial Chemicals Industries (Plastics Division), Ltd.) was also re-elected as Vice-Chairman of the Federation for the new session.

" PERSPEX," which is now released for civil use, has had a remarkable war record and has been used on every battlefield in the world. It has survived extremes of climate, hot and cold, wet and dry, with triumphant success and has, as an aircraft glazing material, stood the test of outdoor exposure for five years without distortion, cracking, deterioration or any physical failing. This important fact will give confidence in the durability of the material under the less exacting conditions of civilian life.

The simple shaping processes by which it can be formed make very few demands on manufacturers, as the moulds can be made by ordinary pattern-making technique and prepared by any competent woodworker. Besides being used by the shaping technique, " Perspex " can be cut, drilled and worked with ordinary woodworking tools. It has already found application for lighting fittings, the guarding of machinery, button manufacture, and for the production of many articles of domestic equipment.

PLASTIC MOULDING.—Alfred Herbert, Ltd., Coventry, has reprinted the excellent article on this subject that originally appeared in " Machine Tool Review." The pamphlet gives an excellent insight into the raw materials and plant available for their moulding in a simple and well-illustrated form. Compression and preforming presses, extruding machines for rod or tube production, cable-covering plant, transfer moulding presses, injection moulding machines, and auxiliary plant, such as hobbing, Keller and Gorton milling machines, and pantograph milling and die-sinking plant, are adequately described.

E. K. COLE.—The head office of E. K. Cole, Ltd., has now returned to Ekco Works, Southend-on-Sea, and matters regarding sales, export, publicity, secretarial and accounts should be referred to that address. Phone, Southend 49491.

TITANIUM PIGMENT MANUFACTURERS' SPECIFICATION COMMITTEE.—Mr. W. A. Cash, of British Titan Products Co., Ltd., has been elected chairman, and Dr. A. N. C. Bennett, of National Titanium Pigments, Ltd., secretary of the committee for the coming year.

SUFLEX, LTD.—Mr. F. L. Hallard has joined Suflex, Ltd., as northern representative and is working from the Manchester office at 2, Brazil Street, Manchester, 1. Suflex, Ltd., are now manufacturing push-back wire, in addition to the usual production of plastic insulated sleeving.

ALFRED HERBERT, LTD., Coventry, announce readiness to supply machine tools for industrial re-equipment on hire-purchase terms, either direct or through established channels.

HILL, NORMAN AND BEARD PLASTICS, LTD., has been registered as a private company with a capital of £75,000 to acquire the business of designers, manufacturers and constructors in plastics carried on by Wm. Hill and Son, and Norman and Beard, Ltd., of Kilburn.

DR. GORDON KLINE, of the Bureau of Standards, and technical editor of " Modern Plastics," is in this country again. He has come on a special mission, but has found time to return in full measure the hospitality he received on his previous visits.

MR. T. W. JONES, who for many years has been Editor of " The Industrial Chemist " and related journals, is appointed Editor and Manager of the Publications of the Society of Chemical Industry.

Planned Mould Maintenance Service Aids Economical Production

Part XIII

By W. M. HALLIDAY

Perhaps one of the most essential mould factors making for successful injection moulding production is that of efficient gating, and where properly designed provisions in this respect are not made, one or all of the following disadvantageous features may be encountered.

Very considerable operating difficulties such as "short-moulding," or "cold shots," may arise where mould gates are incorrectly shaped, located or finished.

The finished product, too, may suffer from serious surface blemishes, weakened sections, poor weld, cracking, or even imperfect formation as a result of unsuitable gates.

The mould also may be subjected to several forms of damage, strain or excessive wear, which in their turn will entail greater attention from the skilled maintenance toolmaker.

The following survey of gating technique, its problems and limitations, will therefore be found of great interest and practical guidance to the maintenance mould engineer in tracking down the causes of puzzling production or tool faults.

Mould Gating as a Production and Maintenance Factor

AMONGST plastic mould designers, engineers, and particularly maintenance toolmakers, it is not always as fully appreciated as it should be, just how important a function proper gating of a mould can play to promote successful injection moulding production. By it, sound, more homogeneous and well-finished products are possible with a minimum of operating troubles.

The author has chosen a special section of this series in which many aspects of gating technique and practice may be discussed, because it is felt that a better understanding of the possibilities and limitations of gating will substantially assist the maintenance toolmaker.

By such an understanding many otherwise bewildering operating or production features which arise from time to time in injection moulding will become far more easy of elucidation. Thereby the person charged with the task of servicing plastic moulds to maintain them at the highest level of efficiency will usually be spared much mental worry and loss of valuable time, which, without such knowledge, may be expended in various cut-and-try endeavours to discover the cause of such troubles.

At the designing stage of the development of a plastic mould several very important considerations have to be held clearly in view, and it is proposed to begin the discussion on gating by first bringing them to the notice of designers, engineers and maintenance men.

General Features of the Good Mould-gate

Just as every mould design and construction is largely an individual engineering or mechanical problem, so with respect to the feed gates supplied for admitting material into the cavity. There are various standardized forms of gate, of course, each applicable for certain purposes; also gate sizes and location in relation to cavity vary very greatly mould with mould. These will be dealt with in some detail at a later point, and a number of illustrations given to indicate best applications.

But there are a number of general features which apply to all gates, which are here listed as being worthy of careful consideration.

(a) It is essential that the gate or gates should be formed of sufficient capacity both in respect of its size, shape and situation, as will enable the mould cavity to be filled under normal injecting pressures, and with due rapidity agreeing with the operation of the injection machine.

(b) The gate should also be so located

has now been established that gates of

Another important consideration to be

in respect to mould cavity or cores, etc., as will ensure best flow conditions to the injected material, so avoiding as far as practicable the presence of air traps, or, on the other hand, excessive turbulence of the material in remote portions of the cavity.

(c) The surface of the gate should be highly polished, in order that there shall be the least amount of frictional restriction imposed upon the plastic material being forced over it into the mould cavity.

(d) In shape, form and layout the gate should be one readily permitting inexpensive machining and finishing off, and also easy access so that modification by hand tools is possible as will be required when the finished mould is placed under its tests prior to production service.

(e) The gate design, size and location should also be such as will facilitate rather than retard the easy or rapid separation of runner and stalk during the subsequent trimming operations to which the finished plastic moulding will be subjected. It should be remembered that in a great majority of cases this trimming operation consists of a purely manual one, whereby the operator breaks off the runner at the gate by finger pressure.

(f) Where possible the gate should take a form which does not too drastically alter the direction of material flow provided by the runner channel, as this may lead to harmful drop in injecting pressure.

(g) The gate should never be machined with undercut portions on its side faces, as this will tend to cause the moulding to hang-up at this point during ejection.

(h) Gate area should be arranged so as to be substantially the same as that of the runner channel.

(i) The juncture of the gate and runner channels should be very smoothly finished off and blended out, so that no sharp or sudden step remains. Wherever possible the bottom of the runner should be gradually run out into the gate area without any sudden or perceptible alteration.

Very much could usefully be said concerning the foregoing nine general features of correct gating, which, it is once again emphasized, will arise for consideration by the designer and mould engineer in connection with almost every mould design. Space allows only the briefest mention being made of some of the main points which are deemed worthy of the especial notice of the mould engineer and maintenance toolmaker.

Size of Gate (a)

Regarding this important question of what size of gate to provide, no hard-and-fast rule can be given. Determination of this question is, of course, essentially a problem of mould design, and will depend to a large degree upon such matters as volume of the moulded article, its configuration, wall thickness, depth of cavity, cores, pressure on the injected material, temperature of plastic material and of the mould.

One commonly adopted method, which seems as good as any, for obtaining gate size is first of all to calculate its theoretical area in relation to runner channel, and with regard to the above-mentioned factors, and to form the gate wide enough but shallow in depth. At the first machining the gate is rarely made more than .020 in. deep.

When the mould is tested, varying pressures and temperatures are employed and the gate carefully deepened at the same time until a perfectly sound moulding is secured. Of course, a considerable degree of skill and experience in such activities is called for in order to be able to distinguish whether any prevailing shortcomings or apparent faults are in reality due to insufficient gating.

For very many years designers and engineers were of the belief that the best method in gating a mould was to maintain it as small as possible in cross-sectional area, the accepted idea being that such a restricted entry would tend to build-up the heat of the passing plastic material, due to extra friction thereby created, and so assist towards preventing the freezing of the plastic flow at this vital point.

This view has now largely given place to a belief of the opposite view, which recent observations have supported. It

has now been established that gates of very small cross-sectional area cause a drastic and in some cases serious drop in the injecting pressure, and thereby is apt to lead to a lack of homogeneity in the finished moulding. It would appear that the fine gate possesses no advantage over the wide gate, except that it is probably easier and less costly to reproduce. But, of course, this latter advantage is nearly always far outweighed by the production of improved mouldings, better flowing conditions to the injected material, less operating trouble, etc., which accrue from use of the large gate.

It is necessary to point out, however, that runners and gates of very large cross-sectional area in relation to area of mould cavity to be filled, very greatly assist in avoiding the "cold shot." This latter-mentioned undesirable feature occurs when thin streams of incoming injected material become partially or completely solidified on the surfaces of mould cavity before the latter is completely filled. It will be appreciated that undue restriction to free flow at the gate entry will both diminish the pressure behind material, and also considerably thin out the stream itself.

It is also difficult to make a rigid ruling on gate size not only because of the many variable factors arising from cavity size, contours, etc., as previously mentioned, but also because the numerous moulding materials used in the injection process vary a good deal in their flowing capacities. So much is this the case that quite apart from cavity volume factors, some materials will be found to need a much larger gate than others in order to counteract their sluggish flow characteristics.

Location of the Gate (b)

In general, gates should be located as near as practicable to those portions of the finished moulding where appearance is essentially important. This is because the last portion of injected plastic material into the mould is usually much hotter than the preceding masses, and therefore affords the better weld, which also means that a much superior surface finish is obtained.

Another important consideration to be borne in mind when determining the location of a gate is so to position it that the material is caused to flow through and from the smaller cross-sectional areas of the mould cavity into the larger areas. This means that for preference the gate should be located upon the thinner sections of the moulding.

The presence of cores or insert pieces will also enter into the determination of gate locations. Where very slender core pins or insertions are near the cavity wall and likely to suffer disturbance from the incoming injected material, the gate should be situated so that the plastic flow does not impinge straight on to such parts.

It has also to be remembered that most injection mouldings are subject to a slight loss of their mechanical strength at the gate and immediately surrounding portions. Thus the gate should not be located at those points on the moulding where maximum strength is required.

In the case of mouldings where surface finish is highly essential, care should be taken to situate all gates upon inconspicuous surfaces to avoid flow and weld lines from being formed thereon.

Surface Finish of the Gate (c)

This, too, is an important factor, and a little additional time expended upon securing a high smooth polish will well repay the mould engineer. This is one of the points which should be carefully watched from time to time by the maintenance toolmaker, and is one which will certainly call for periodical retouching up and repolishing. Many injection moulding materials are considerably abrasive, and a good proportion of this action will be concentrated upon the surfaces of the gate. From practical experience the toolmaker will speedily learn which materials cause the most damage in this respect and so will arrange for those moulds to receive closer and more frequent attention.

Shape of Gates (d)

If it is not practicable to lay down rules for the size of a gate without reference to all the other factors already dealt with, it is possible to lay down a reliable guid-

ing rule governing the best shape of a gate. It will be found that cylindrical or elliptical shapes give the best results. Incidentally, these are the preferred shapes for the runners.

Unfortunately, it is not always possible to adopt one of these shapes because too large a gate entry in relation to mould cavity to be filled may result. In such instances the gate may be made rectangular with flared sides. It is usual to make such rectangular gates with sides inclined at about 60 degrees.

In respect of the machining of these various shapes of gate it will probably be less expensive to form the cylindrical type than the others, as this will mean a straight cut through with a suitably shaped cutter, which will form correctly the full surface of the gate at one pass, whereas with the rectangular gate having inclined sides, it may be necessary to make two or three passes to form the complete gate.

As pointed out under item (i), it is essential that the gate be free from all undercut portions, and also that no step be left at the point where runner and gate meet. Better flowing conditions of the material will be maintained if the runner smoothly runs out to the gate passing imperceptibly from runner depth to gate depth. The gate will, of course, widen out in order to maintain cross-sectional area in relation to runner area.

Gating to Facilitate Trimming (e)

In cases where it is necessary to have a deep and narrow rather than shallow-wide gate, difficulties may arise when the finished mouldings reach the trimming table. It will be harder to break off such gates to remove the runner and stalk piece. This is yet another reason for care being taken in machining the gate depth, and wherever the shape of the cavity renders it practicable, width rather than depth should be the chief aim in gate form.

Gates can, however, be adapted in their shape to assist trimming, and in particular will this be required where the gate must be located upon an important surface of the component which must be kept free from scar. By a slight alteration in its shape the gate may be fashioned so that the point of fracture from edge of moulded article is not located dead on its edge, but withdrawn back slightly. The shallowest part of the gate in this adapted form will not be at the extreme edge of the cavity wall, but a slight distance back, say, approximately $\frac{1}{16}$ in.

This will leave a slightly raised piece of gate on top of the finished article, which can then be finished off without incurring the risk of breaking off the edge of the part.

In some mouldings branched runners and gates sometimes have to be used, and in this connection care must be taken to locate both branched portions upon the same face of the moulding. If the branches are situated on non-coincident lines of the part, difficulty will be encountered in breaking off the finished moulding.

As will doubtless be inferred from the foregoing description, if due consideration is given to these more general features of gating technique and practice, very much improved moulding production will ensue, which, in turn, will be characterized by better products, smoother working of the moulds, lessened demands for the skilled services of the maintenance toolmaker to maintain the tools in first-class operating condition.

Obviously, to a great extent, the forementioned features should be incorporated into the mould design and construction at the earliest possible stages of its development. Unfortunately, it is often mistakenly thought advisable to leave close attention to gating provisions until the mould construction has become well advanced and approaching the testing stage. Where this is done, however, very often it will be found impossible to locate gates in the most appropriate situation because of the risk of interfering with other important provisions of the mould. The result is, in such circumstances, that some disadvantage is occasioned and, in extreme cases, the mould may be inadequately fed with

No. 7. APPLICATIONS OF PLASTICS

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. . . and give a notable performance. In this instance a high shock resisting plastic is used to shroud the radio aerial loop on aircraft.

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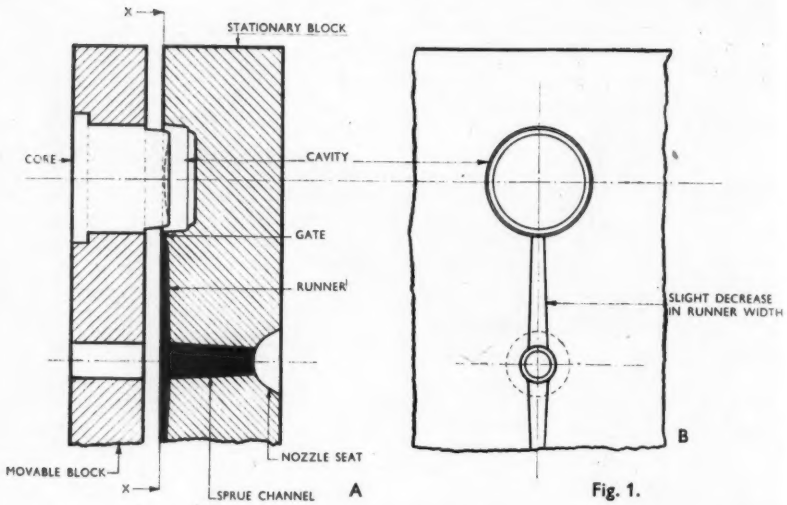

Fig. 1.

resultant troubles during moulding and unsatisfactory products.

Very often the maintenance toolmaker, arising out of his specialized knowledge and experience of mould operation, wear and behaviour, will be able to offer sound and useful advice to the mould engineer when machining, readjusting, or altering mould gates, etc. He will certainly be in a good position to recommend the most suitable form of gate, together with surface finish likely to give the best working results.

Types of Mould Gate

The exigencies of mould design and cavity disposition or shape entail the use of one of the well-established four distinctive kinds of gate, each of which has its own particular applications for which it is best suited, and which in actual practice have been well proved. These four kinds of gate are described and illustrated in turn as follow:—

The design of the required moulding, i.e., whether its shape is flat, thin, and of extensive surface area; or long, narrow and tubular; or large-sized hollowed-out form, etc., will largely determine the designer's choice of gate, and, of course, careful attention must be given to the above points before gate form can be finally settled. Volume of material required to form the moulding, together with its length of travel, will also have a considerable influence upon the type of gate to be employed.

The Straight-in Gate

The type of gate illustrated in Fig. 1 is perhaps so widely used for a wide variety of moulding shapes and sizes that it may be regarded as the standard gate form. Certainly, when one bears in mind the several very slight modifications that may be effected to its shape so as to cover some unusual circumstance or feature in the required article, a very high proportion of injection moulds are gated according to this manner with excellent results, both as regards the finished part and freedom from snags during production.

In essence, this gate consists of a shallow run-out of the runner itself, coupled with a slight increase in its width as the depth thereof decreases.

The sketch in Fig. 1 shows a sectioned view of the upper portion of the mould blocks to indicate the feed to one cavity, although actually this is a two-cavity

tool. The right-hand view shows the upper impression and the layout of the runner and gate in relation to both sprue channel and cavity, viewed from parting-line along X-X.

Several important features are worthy of note in respect of this type of gate and its feeding runner.

In the first place, it will be observed that the runner and gate is located in the stationary mould block, into which the cavity impression is formed. The movable block contains a fairly large diameter core piece on to which the finished moulding will shrink with sufficient grip to enable it to remain thereon whilst the moulds are opened. This will result in the waste stalk or sprue, runner and gate all being withdrawn from the stationary block at the same time, and then ejected integral with the moulded article. This is an important consideration which has to be closely watched, otherwise ejection difficulties may arise.

Sometimes it will be necessary to form the runners and gates within the movable mould block, at other times it will be found that best results are obtainable by locating, say, the runner in the movable block, and the gate in the stationary one, suitably arranged to ensure correct feeding, of course.

Next it will be noted that the width of the runner decreases as it approaches the edge of the mould impression and nearer the gate. This is often found of very great assistance in obtaining ample flow, as it permits a build-up of material along the runner. Its use also maintains the pressure on injected material to some extent.

Thirdly, the gate is formed with a gradual running-out of the runner in regard to its depth. The entire length of runner is made so that its bottom gradually decreases in depth from parting-line surface, but usually from a distance of approximately $\frac{1}{4}$ in. from edge of mould cavity; this decreasing depth is sharpened appreciably, as shown. This latter is continued until about $\frac{1}{16}$ in. away from entry into the cavity, the remaining short distance then being left parallel, as shown in the sketch, or modified in ways which will be referred to later. At the juncture of runner and beginning of the gate proper the two portions are smoothly blended into one without any visible interruption.

Although not specifically shown in the sketch, the cross-sectional shape of this runner and gate is approximately elliptical, this being blended out to a somewhat flattened shape at the gate. Cylindrical and flat-bottomed runners and gates are extensively used, with good results, but, in the case of the latter, care must be taken to provide slanting sides of sufficient inclination to allow easy removal of the runner, etc.

This form of gate possesses several very useful advantages, which greatly commend its use. These are:—

1. Easy reproduction by either milling, grinding, or die-sinking machines, and usually no additional machining operations are entailed other than those required for producing the runner. This is of appreciable importance to the toolmaker, in that he is relieved from having to make special set-ups of the mould blocks on other machines, or to provide unusual tools and cutters in order to machine the gate. Thus, on the score of economy, this type of gate is deservedly popular.

2. It is one which is readily adjusted in depth or width, either by hand or portable machine, such as the grinding head, and generally such operations can be performed even when the mould is set-up on the machine platens. This facility promotes quick alterations being made without incurring the trouble and loss of time required when the mould has to be removed.

3. Removal of the finished moulding is also greatly facilitated with this type of gate, and if appropriately finished off with a high surface polish little trouble should be occasioned by sticking mouldings.

4. Ensuing trimming and gate-removal operations are usually of a very simple character, consisting of a breaking-off of the runner, stalk, etc., at the gate

juncture with moulded article. Since this junction portion is both narrow and thin, and located along one plane, the complete feed may be rapidly broken away.

5. Very little scar or disfigurement is left on the finished moulding from this type of gate since it embraces but a tiny portion of the surface of the moulding as will be seen from Fig. 1, right-hand illustration. On mouldings where surface finish is highly important this is a very valuable feature and leads to savings in the finishing operations succeeding moulding, as well as promoting the maintenance of correct shape and sizes of the moulding.

6. The gate can be used with equal facility and good results on either single or multi-impression tools, and may be employed in conjunction with either single, straight, or branched runner formation. This latter usually is required when the mould has a number of cavities.

The straight-in gate cannot, however, be employed for the feeding of every kind of mould cavity. One kind of moulding for which it is obviously unsuitable is that having a very extensive surface area in relation to thickness, such as shallow, tray-like articles. The feeding of parts of this shape entails that the incoming plastic stream be given a distinct tendency to spread outwards. Again, large disc-like shaped articles cannot satisfactorily be gated by the straight-in method, especially if the part is so large that the single cavity impression must be disposed concentrically around the sprue head.

Referring to Fig. 2, the left-hand sectioned view A shows a very undesirable gate shape. It will be noted that the runner increases in depth as it leaves the sprue channel head until it reaches the beginning of the gate itself. Here the reduction down to gate depth is very marked, causing a very substantial step to be left at the juncture.

This step will produce several unsatisfactory features, such as a drop in injecting pressure due to it serving as a baffle to the injected stream of plastic material. There will also be excessive wear on the gate surfaces due to the abrasion set up by the too drastic interference with material flow at this point. Following from these two disadvantages it often happens that freezing of material occurs in the gate, leading then to incomplete filling of the mould impression and loss of homogeneity in the finished moulded article. The writer has also observed that such a runner-gate formation may lead to sticking of the moulding due to severe roughening of the surface of gate and runner on and surrounding the step, the correction of which calls for the frequent and repeated attentions from the mould maintenance engineer.

The right-hand view B of Fig. 1 illustrates a very useful and commonly used modification to the straight-in standard gate. The purpose behind this alteration is to obviate the loss of the sharp edge on the finished component which occurs sometimes when the normal gate excess is broken off. In some instances it is not possible to treat the feed edge of the finished article to remove the slight scar and restore the sharp edge at the point where the gate has been located.

This may easily be circumvented by altering the gate to the shape shown at B. Here it will be seen that the shallowest point of the gate is brought backwards a slight distance away from the edge of moulding cavity. This means that when the runner and stalk are broken off the finished article the break will take place along the line indicated instead of at the extreme edge of the moulding.

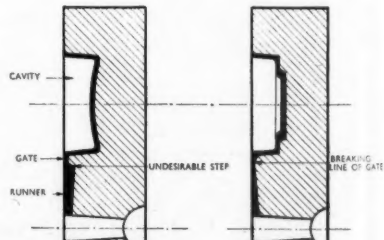

Fig. 2.

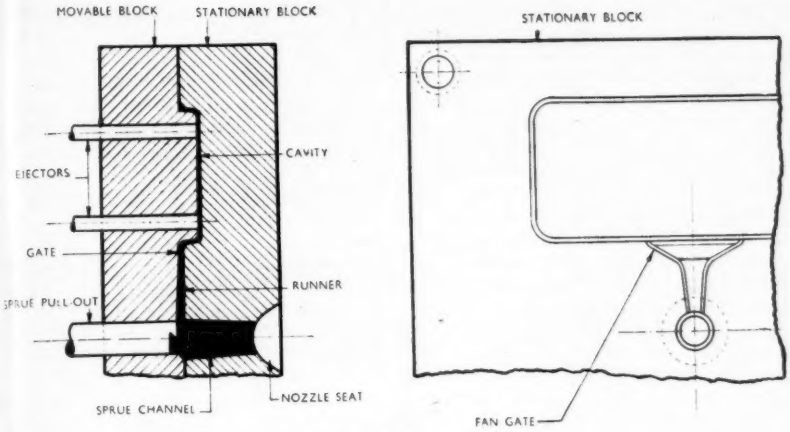

Fig. 3.

True this will leave a slight projection, but this can easily be removed down to edge of the component, or, at any rate, much easier than a broken edge could be restored.

This is a very useful point to bear in mind as its use may eliminate lengthy and costly trimming and finishing operations otherwise necessary.

The Fan-type Gate

This second conventional type of gate, known as the fan type because of its shape, is extensively used for feeding mouldings of large surface area and thin cross-sectional dimension, such as plates, trays, and the like.

As already discussed, the chief function of the feed for such moulds is that of providing a dispersal of the stream immediately prior to its entrance into the mould cavity, so that flow shall be initiated and then maintained in divergent directions, thereby ensuring more rapid and complete filling of the cavity.

By such a dispersal of the flow direction improved surface appearance is obtained as the flow marks are reduced and imperfectly formed mouldings made less frequent.

The formation, application, and use of the fan gate are clearly illustrated in the two views shown in Fig. 3. The one to the left hand is a partial sectioned view of the tool with the mould blocks in the closed position. The upper cavity only is shown.

The right-hand view is that seen looking at the parting-line surface of the stationary mould block. It will be seen that the moulding is very shallow but possessing considerable surface area.

The runner and gate shown are made flat bottomed with sharply flared sides. It would be easily possible to make the runner semi-circular or even elliptical in cross-section, blending out the gate into a flat shape with inclined sides. The runner width gently increases until reaching the gate itself. This latter then fans out each side of the runner, making a very wide engagement with the side of the mould cavity as shown, and at the same time decreasing in depth.

Because of the large length of such a gate its depth can be maintained very small, thereby ensuring a very small scar or marking of the edge of finished moulding, and also permitting easy breaking-off of the stalk and runner waste.

On articles of this type, fed by means of the fan gate, it is often necessary to employ the sprue pull-out rod of the type shown in the left-hand view Fig. 3. Such

an arrangement consists of a cylindrical rod capable of sliding closely but freely within the horizontally bored hole through the movable mould block located exactly in line with the sprue channel formed in the stationary block. The end face of the pull-out rod is usually stepped and dovetailed in the manner shown in order to ensure a substantial grip upon the sprue stalk, which, of course, is moulded around the dovetailed portion.

Use of this provision obviates the unsatisfactory feature of the moulding, breaking off from its gate during the opening of the mould blocks, which is prone to occur with the very thin fan gate and large mouldings. The finished moulding is usually pushed off the core projection formed on the movable block by means of ejector pins as indicated.

In cases where a moulding having a very long side has to be fed it is, of course, possible to split the fan gate and employing two such like feeds from a branched runner.

The Ring Gate

When hollow deep tubular or cylindrical mouldings have to be made, neither the straight-in or fan gate will suffice for ensuring adequate trouble-free feeding. In such instances the designer must resort to a third type of gate known as the Ring Gate, which is fully illustrated at Fig. 4.

Here again two views are shown, the one to the left hand being a cross-section of the assembled tool, whilst that at the right is the view seen looking at the parting-line of the stationary block.

The moulding comprises a deep cylindrical beaker-like article cored out by means of a large fixed core member situated in the movable block.

The gate itself entirely encircles the large end of the cavity, and is located in the stationary block as before. The runner widens appreciably after leaving the sprue head, and moreover it will be noted that depth is made considerable, especially at the point of juncture with the sprue stalk.

This kind of gate possesses several useful features.

Thus it is one capable of easy production; it only requires a shallow recessing of the mould block immediately around the mouth of mould cavity.

Another advantage is that it permits the filling of the cavity much more evenly and uniformly. This results in the avoidance of unsightly weld lines, effects of shrinkage, and partial segregation of plastic flow in remote portions of the mould cavity. Feed is more or less secured from all sides of the cavity, in contrast with that obtaining from single-point feed and gating. This means that the flow will take place around the core member down to the remoter parts of cavity.

This kind of gate is, however, attended with one big disadvantage in that the article will have to be finished off in some way to remove the complete ring gate which will be attached to its end face. This is usually performed on a small belt-type finishing machine, or grinding machine, and cannot simply be broken off as in the case of the standard straight-in gate. Because of this drawback allowance must be made on the length of the moulded article, as will be noticed from reference to sketch at the left hand in Fig. 4. The gate thickness is added to the overall length of the moulding.

Ejection of the finished article is secured by the use of a sliding stripper plate. In this connection, incidentally, several points of interest arise for the maintenance engineer, which may be briefly noted in passing.

The sliding stripper plate is operated at a certain point during the opening movement of the mould blocks, and the further travel of the movable block thus causes the finished moulding, together with runner, and sprue stalk, to be pushed off the stationary core piece.

Sometimes moulds are arranged for the stripper plate to slide along the plain shank portion of the core, but this is to be discouraged for several reasons.

Heat, dirt accumulations, expansion of core or lack of lubricant all may cause stiffened working of the stripper plate

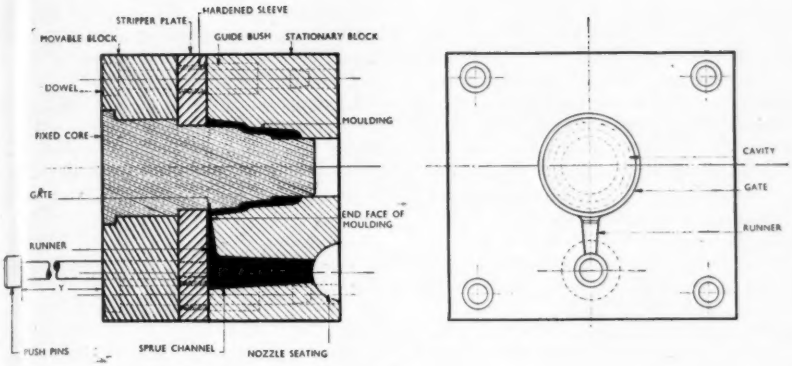

Fig. 4.

thus positioned, which in turn will lead to increased wear of core and bored hole in stripper plate. Flash will result from such wear, and the mould will develop noisy, jerky motion during opening and closing operations.

In the illustration it will be observed that the stripper plate not only locates upon the cylindrical core but also upon the four substantial dowels situated at each corner of the blocks. Hardened steel liner bushes are provided in the holes in the plate, so that easy renewals and restoration of original hole size are obtained.

Another important point concerns the method of arresting the movement of the stripper plate. This is secured by the use of headed push pins, one of which is shown. A number of these pins are located at suitable points on the stripper plate, passing through plain holes in the movable mould block, and screwed down into blind tapped holes in the rear face of the stripper plate. These push pins should be made a smooth, sliding fit within the block, and thus used to assist the guidance to the travel of plate.

With the blocks and stripper in the closed, moulding position, as shown, the distance "y" from rear face of movable block to underside of the head of the push pins should be sufficient to ensure complete ejection of the finished article.

By this arrangement once the finished part has been effectively shed from the fixed core, the stripper plate is automatically returned to its closed position by the normal bringing together of the two mould blocks in readiness for the next injection "shot." No springs, etc., will be needed to return the plate, whilst the head portions of push pins prevent it from passing clean off the fixed core during actual ejection.

The push pins should be located as near the fixed core or cores, upon which the stripper plate has to slide, as is practicable, so avoiding the troubles likely to arise from a distorted or bending stripper plate, which may occur if the pins are located near the extreme edges of the block and far removed from the point where ejecting or stripping pressure has to be exerted on the finished moulding.

Stripper plate mould constructions call for a little extra care from the maintenance engineer, because several possible sources of trouble can be associated with such mechanisms if regular inspection and attention is not afforded their use.

The Disc-type Gate

The fourth type of conventional and much-used gate is illustrated at Fig. 5, which shows a cross-sectioned view of the completely assembled mould (see the left-hand figure) and a view partially across the parting-line surface of the mould as at the right hand.

It will be observed that the moulded article in this instance is actually a ring-shaped piece of large outside diameter, which entails the use of a single impression mould. The diameter of its internal hole is also fairly large. The cavity impression is more or less concentrically located around the sprue channel, as shown, and feeding is accomplished by linking up the periphery of the inner edge of cavity with the sprue head by means of the disc-type gate, which consists of a shallow recess machined all the way round between the sprue and beginning of the cavity, as indicated.

Actually this type of gate may be considered the reverse of the ring type previously mentioned.

It will also be noted that the runner is virtually eliminated in this type of gate, especially in those cases where the inner diameter of the annular moulding is small or not more than, say, three times the diameter of the sprue head. Where very large articles have to be fed in this manner a number of radially disposed runner channels may be provided to bridge the disc gate with the sprue feed. This arrangement will ensure better flow and also serve to reduce the amount of waste material incurred in the stalk, runner and feeds generally.

Use of such a form of gating from the centre rather than the periphery allows the injected plastic material to flow radially in all directions, thereby reducing the tendency to form unsightly surface markings, bad weld lines or flow marks upon the finished article.

Referring to Fig. 5 and the left-hand sectioned view, it will be seen that the disc-type gate is restricted somewhat in depth from a point near to its entry into cavity area. The reasons for this are several, thus:—

When the moulded article is ejected severance of the gate and stalk portions will be appreciably facilitated and simplified if the material thickness at which the break has to be made is maintained as thin as possible. If this is not watched it may be found that the removal of the gate, etc., requires application of considerable force, and might easily mean the setting up of a special cropping tool in a fly press, so that the waste gate could be punched out. Where the gate is of necessity of undue thickness, care will have to be exercised during trimming and punching-out operations lest the moulding surfaces be scarred or left jagged, due to the heavy pressures required for punching through the gate, and the consequent uneven breaking away of the material on the underside.

Furthermore, as will be appreciated, the surface area offered by a disc-like gate of the kind described will obviously possess very much greater surface area than the standard straight-in or fan types,

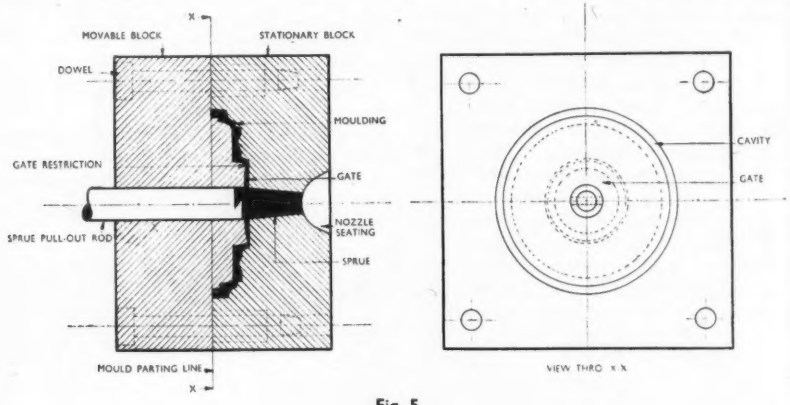

Fig. 5.

hence it is possible in many applications for the designer to specify very shallow gating, especially at the point closest to its entry into the mould cavity.

A third reason will also be apparent to readers from an understanding of the chief function of this type of gate. Essentially its purpose is to effect a very extensive radial dispersion of the incoming material, so that flow is practically simultaneously directed to all portions of the annular component being produced. If the gate is made too deep, then too large a volume of the plastic material will find entry into the cavity at points immediately surrounding the gate nearest sprue head. A slight restriction of entry ensures greater spread.

Nearly always such a disc gate has to be removed by a simple punching operation on a bench press, by the use of a punch cutter or die made almost the same diameter as that of the internal hole in the finished moulding. These operations, if they are to be performed economically, quickly and safely, with a minimum of scrap, require suitable punches and die plates, as well as provisions thereon for ensuring correct alignment of the component to be punched, so that the punch tool correctly aligns up with the internal hole in the part.

Much could be written of the snags and production troubles which may arise throughout such operations in cases where there is no maintenance supervision as to care of punches, die plates, presses, etc. If tools and punches are allowed to get misaligned or become too blunted at their cutting edges, excessive scrap will result.

Another important point to bear in mind in respect of the use of the disc gate is that nearly always it is advisable to employ a positive sprue pull-out, as shown in Fig. 5. This, of course, applies only to those designs where the core members for forming the internal shaping of the article are situated on the movable block in the manner indicated. If such a means is not provided, any sticking of the sprue stalk within the channel in stationary block may cause the gate to be badly distorted, and even fractured at some points. Should this occur the moulded article itself may suffer from distortion, and breaking away at the sharp edges of cavity adjacent to gate. This will be important when dimensions on the moulding have to be maintained within small limits of error, as any distortion occurring during ejection will tend to alter such essential dimensions.

These, then, are four of the chief kinds of gates employed by moulders, but it must be understood that gates of slightly modified shape or form can, of course, be employed, and, indeed, are often necessary in order to effect satisfactory feeding of an unusual cavity form or layout.

Thus, in the case of the fan, ring and disc types of gate the runner may be branched instead of confined to a single channel, and the gate similarly branched in order to obtain feed to parts of the cavity which otherwise may be inadequately supplied. In the case of the straight-in type of gate used on multiple impression tools, it may be advisable to make the runner in the form of a long, straight bar, and sub-runners leading from this to the gate of each cavity.

But generally it may be said that whatever form the gate may take, it will fall within one of the four classes already mentioned.

Before dealing with the usual kinds of maintenance requirements occasioned by runners and gates, and the particular service attention required on behalf of the toolmaker to ensure smooth operation, sound mouldings, a minimum of scrapped or faulty parts, and freedom from serious mould damage, it will be advisable to discuss the function and purpose of the mould runner and gate from another important angle, often overlooked.

Runners and Gates in Relation to Temperature Balance of Mould

As intimated above, it is not always appreciated that the runner and gating system of a mould has a dual function to perform. Not only must it effectively convey the flowing plastic material from sprue to mould cavity, but it must also

assist in maintaining the temperature equilibrium of the mould itself.

Because of this second purpose, and contrary to widely held belief, the size or capacity of both runner and gate does not necessarily need to be directly proportional to the volume of material absorbed by the component being produced, and, therefore, the necessary sizes of runners and their gates can actually be effectively combined within a small compass.

For example, in a mould containing a number of impressions, shaped to produce mouldings of very thin section, the heat transferred from the injected mass of plastic material to the mould during the process of solidification will not be sufficient to maintain the moulds at the requisite working temperature, if the runners and gates are directly proportioned with respect of cavity volume alone or to the weight of the finished parts, which amounts to the same thing.

As a result of the drop in the optimum mould temperature due to this cause, it may be found that excessively rapid chilling or "freezing" of the material occurs, especially on the outer edges of both runner and gate. Should such a premature solidifying arise, the flow of material into the cavity proper may become seriously impeded, resulting in imperfectly moulded articles and the possibilities of mould damage developing during ejection stages, as previously discussed.

In contrast to a mould of the above nature, if one is provided with a cavity or cavities for forming a moulding of large area and thick cross-sections and of heavy weight when finished, the provision of a runner-gate system proportionate to such a material weight or volume will give rise to rapid elevation of the mould working temperature. Such a condition will be distinguished first by prominent surface defects, such as deeply striated flow markings, imperfect welding and so on, and finally by excessive distortion of the finished products and difficulties in securing their ejection out of the mould.

Moreover, production is apt to be retarded by these conditions, as it will be necessary to allow a slightly longer dwell when mould blocks are in the closed position, to permit the full solidification of the plastic material contained within the runner and gates.

The temperature balance of the moulding tool is chiefly determined by the proportions of the volume and surface area of the complete spray or set of sprays. Consequently, where unbalance in mould heat arises from the production of a moulding too thin or too thick, temperature counter-balance may be secured by the layout and proportioning of the runner-gate system of the mould.

Of course, there is another expedient open to the moulder engineer by means of which the thermal balance of a mould may be promoted. This is by recourse to water-cooling or gas or electric heating of the mould or portions thereof.

Whilst these latter alternatives certainly permit simple means for redressing too violent increase or decrease of mould temperature, they also render the moulding tool much less self-contained, and, moreover, create an additional operating factor, whose control is largely in the hands of the operator and, therefore, liable to considerable variations. Their adoption also usually entails some increase in mould costs and setting-up time when the latter is installed on the injection machine in readiness for the production run.

Their use also must be brought in judiciously, otherwise the mould may be unduly cooled off or excessively heated in some portions, as to result in a worsening of the conditions to cure which they were called into action. Only very rarely can such means be regulated that heat is correctly applied or taken away from the appropriate portions of the mould.

It is emphasized that such cooling or heating methods are but poor expedients in most instances, and the troubles they aim at curing can best be eliminated on the drawing board, when the mould design is in its paper stage, by means of an intelligent understanding of the technique of runner and gating requirements, and the most suitable locations of such mould members to produce best results.

In fact, good layout of mould cavities and location of runner and the gates can often serve very materially in securing thermal balancing of the mould.

The aim of the designer should be to secure as even a distribution of heat all over the mould-block members, and for this reason those portions of the moulded article from which more heat requires to be withdrawn, which are the thicker sections, should be situated generally at greater distance from the sprue head, runner and gate than the thinner sections.

In mouldings where there are no portions of large cross-sectional thickness, it may be advisable to arrange means whereby extra heat may be added to the mould at the extremities of the moulded article.

The author realizes the complexities of this aspect of mould design, and regrets that space limitations forbid the presentation of illustrations of various types of mould cavity layout designed to promote thermal balancing of the mould. It is hoped that enough has been discussed, however, to indicate at least the general features which should be borne in mind both by the designer and mould engineer. The problems raised during actual production as a result of temperature unbalance will very often demand the attentions of the maintenance mould engineer to effect satisfactory solutions, and, therefore, it is suggested that this latter personage should possess understanding of the need for securing such thermal balance, and of the troubles which ensue where it is absent.

General Maintenance Requirements of Gate and Runners

To conclude this section it now remains only to remark upon a number of the more general maintenance features which arise in connection with gates and runners of the injection mould. These are very briefly as under:—

(1) There should be very frequent inspection or examination of the gates and runners for signs of surface wear, and consequent loss of shape. In the case of flat-bottomed, slant-sided gates and runners often there develop slight undercuts on the sides particularly, or the formation of slight steps on bottom surface. Tiny portions of metal may become chipped off during progressive production runs. All these conditions may cause sticking, or hanging of the feed material when the moulding is being ejected, which in turn may then cause bending of slender ejector pins, displacement of cores, etc.

In fact where a mould is maintained in more or less continuous production, it will often be found advisable to arrange for a regular repolishing of the runner and gate surfaces in order to avoid the initiation of the above-mentioned faults. Such repolishing will, of course, be done by hand-lapping stone so that the minimum of materal is removed.

(2) Because the surface of the gate and runner is subjected to considerable abrasive action by the passage of the plastic material, there is a strong tendency for these surfaces to become roughened in time. Rectification of such undesirable condition should also be periodically undertaken by repolishing operations.

(3) Particular attention should be devoted to the close examination of the surfaces of gate at the point where it joins up with the runner. Especially will this be required if a step has to be left at this point, as the pressure concentrated on such a step will be very considerable, and likely to lead to a breakdown of the material of mould at this point.

(4) Where the mould is chromium-plated, sometimes peeling of the plate is to be observed on the gate surfaces. Any signs of lifting should therefore be carefully watched for, and immediately corrected.

(5) The operator should be forbidden to use any kind of hard metallic tool or article for prying out a sticking moulding, as this may cause damage not only to the cavity walls, but what is equally as important, to the sides and surfaces of the runner and gates. This is a very common mould trouble, and the writer has found it the best plan to institute provisions and methods whereby the operator is unable

to use such appliances for these purposes.

(6) With some thermoplastic materials staining of the mould surfaces occurs, and if this is allowed to develop excessively in respect of the runner and gate surfaces, flow may be impeded and wear on the surfaces themselves hastened thereby.

(7) It is worth mentioning that usually some wear occurs at the point where the runner leads out from the sprue channel head, as this generally is in a direction different from the flowing material along the sprue channel. It will be found that the sharp edge tends to become worn away, and after a time presents a somewhat jagged appearance, being rough to the feel. This should be carefully polished, so as to restore smoothness and sharpness of outline.

(8) In some mould constructions it is often found convenient to eject on to the gate or runner as well as the moulding itself. Where this is done will usually incur some additional inspection attention on the part of the maintenance engineer. He will have to examine frequently to observe whether the extremities of the ejector pin holes breaking into the gate area are becoming bell-mouthed. If such a feature develops, trouble may arise during ejection, as the bell-mouthed portion will be filled up with plastic material during each " shot," and may be difficult to extract. It may also cause binding of the ejector pins, and will almost always result in an unsightly marking of the finished part, which may not be entirely removed when the gate portion is broken.

(9) Some little care will also be required when moulds are withdawn from production, and are being cleaned and greased, etc., in readiness for storage. Here again it is equally essential to ensure that gate and runner surfaces do not become corroded, and the same protective procedure should be afforded them as is given to the mould cavity surfaces. During dismantling, too, care should be taken lest the mould is inadvertently placed parting-line surface downward upon some hard object and damage inflicted to the sharp edges of the runner and gate.

Finally, whilst this discussion is by no means exhaustive of all the many practical points connected with efficient gate and runner design and construction, the main considerations of the gating technique have been dealt with as they will affect mainly the maintenance toolmaker, who will thereby be enabled the better to assign the cause of moulding troubles, and able to suggest remedies with greater readiness and confidence.

In the next section, the author will deal with the important problems and their solution of mould constructions incorporating inserts locating and holding devices, with especial attention being directed to the methods of overcoming such drawbacks as are noted.

Moulds of this type usually contain numerous specialized features, such as full, or semi-automatic location and feeding of the insert pieces to the mould cavity. In other constructions such operations are performed manually, and entail the use of special tools, or equipment, the care and maintenance of which in sound working order falls within the scope of the activities of the mould maintenance toolmaker, and therefore is worthy of consideration with a view to an improved planning of the requisite inspection, testing and maintenance services.

Melamine Resins

In our description, in the May issue of this journal, of the production for the Navy of a cafeteria-type tray by Streetly Manufacturing Co. we made no reference to the source of the melamine moulding powder employed. We have now much pleasure in reporting that the melamine mouldstuff, as it is called, is made by Beetle Products Co. at Oldbury.

We are delighted to hear that, following the introduction by the same company of melamine resins for lacquer making, this important step has been taken, for we have long regarded this series as important for the production of many industrial and general goods.

Resinoids and Other Plastics as Film Formers

By B. J. BRAJNIKOFF,
Consulting Electrical Engineer

XXIV.—Synthetic Coatings Based on Acetylene (Contd.)

AMONG the works devoted to the synthesis of film-forming substances and kindred compounds derived from acetylene the studies of Nazaroff, a pupil of Favorsky, occupy a prominent place.

Nazaroff's attempts in synthesizing the so-called vinylethenylcarbinols with the object of paving the way, by means of these unsaturated alcohols, to further synthesis of all kinds of polymerizable ethers were very fruitful. The problem set by the investigators was to find a method of rearranging the molecule of the ether of vinylpropiolic acid. Syntheses of this nature could be approached via two routes. The first of these may be realized by the action of magnesium-bromovinylacetylene upon aldehydes, ketones and oxides of olefins, which should lead to the production of tertiary, secondary and primary vinylethenyl-carbinols, the course of whose reactions is given, respectively, by the schemes I, II and III.

A second method of synthesis of alcohols of this kind is offered by the application of the well-known Favorsky reaction for producing acetylene alcohols, to a direct condensation of vinylacetylenes with ketones. By making use of this, Nazaroff and his co-workers were able to obtain and to examine a large number of primary, secondary and tertiary vinylethenylcarbinols, all of which are distinguished by remarkable ability to polymerize. Depending on the individual structure, these alcohols polymerize with varying speed, undergoing a gradual conversion to gel from a mobile liquid, and, finally, to a hard, colourless transparent resinous solid. Being very stable compounds, all such alcohols and their ethers are readily distillable under relatively low vacuum, and, with the aid of stabilizers, that is, suitable anti-oxidants and other agents inhibiting polymerization, may be kept in storage for long periods.

A close examination of the aforesaid vinylethenylcarbinols conducted by Nazaroff at the Institute of the Organic Chemistry of the Russian Academy of Sciences, recently resulted in a great range of diverse products, which give outstandingly superior film-forming media and exceptionally strong adhesives, binders, and kindred compositions. They can be made to yield coatings that are converted to the solid gel state with or without oxygen and with or without heat. The films derived from them are characterized by having, in addition to striking adhesion, the attractive combinations of desirable properties, such as absence of colour, toughness, chemical inertness, dimensional stability and elasticity.

The noteworthy feature of these carbinols is the influence of certain elements of their structure on the velocity of polymerization. A comparison of polymerization speeds of such alcohols obtained from vinylacetylene and isopropenylacetylene reveals that even a slight branching off in a respective hydrocarbon chain exerts a marked influence upon the rate of polymerization. All the vinylethenylcarbinols—the primary, secondary and tertiary—derived from vinylacetylene polymerize far more quickly than do the corresponding carbinols secured from isopropenylacetylene.

As an outcome of the detailed study of the vinylethenylcarbinols, Nazaroff and his co-workers discovered that these

(I) $CH_2=C(R)-C\equiv CMgBr + \underset{\diagdown O \diagup}{CH_2-CH_2} \longrightarrow CH_2=C(R)-C\equiv C-CH_2-CH_2OH$

(II) $CH_2=C(R)-C\equiv CMgBr + R'\overset{\overset{O}{\|}}{C}H \longrightarrow CH_2=C(R)-C\equiv C-CHOHR'$

(III) $CH_2=C(R)-C\equiv CMgBr + R'COR'' \longrightarrow CH_2=C(R)-C\equiv C-\overset{\overset{R'}{|}}{\underset{\underset{R''}{|}}{C}}-OH.$

(IV) $CH_2=CH-C\equiv C-\overset{\overset{R}{|}}{\underset{\underset{R}{|}}{C}}-OH + R'OH \longrightarrow CH_2=CH-C\equiv C-\overset{\overset{R}{|}}{\underset{\underset{R}{|}}{C}}-OR'.$

(V) $CH_2=CH-C\equiv C-\overset{\overset{R}{|}}{\underset{\underset{R}{|}}{C}}-OH + CH_2OH-CH_2OH \longrightarrow$

$\longrightarrow CH_2=CH-C\equiv C-\overset{\overset{R}{|}}{\underset{\underset{R}{|}}{C}}-O-CH_2-CH_2OH,$

and $CH_2=CH-C\equiv C-\overset{\overset{R}{|}}{\underset{\underset{R}{|}}{C}}-O-CH_2-CH_2-O-\overset{\overset{R}{|}}{\underset{\underset{R}{|}}{C}}-C\equiv C-CH=CH_2.$

(VI) $CH_2=CH-C\equiv C-\overset{\overset{R}{|}}{\underset{\underset{R}{|}}{C}}-OH + CH_2OH-CHOH-CH_2OH \longrightarrow$

$\longrightarrow CH_2=CH-C\equiv C-\overset{\overset{R}{|}}{\underset{\underset{R}{|}}{C}}-O-CH_2-CHOH-CH_2OH$

and

$CH_2=CH-C\equiv C-\overset{\overset{R}{|}}{\underset{\underset{R}{|}}{C}}-O-CH_2-CHOH-CH_2-O-\overset{\overset{R}{|}}{\underset{\underset{R}{|}}{C}}-C\equiv C-CH=CH_2$

(VII) $2CH_2=CH-C\equiv C-\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{C}}-OH \longrightarrow CH_2=CH-C\equiv C-\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{C}}-O-\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{C}}-C\equiv C-CH=CH_2.$

(III) $$CH_2=CH-C\equiv C-\overset{\displaystyle R}{\underset{\displaystyle R}{\overset{|}{\underset{|}{C}}}}-OH + CH_2OH - CH_2OR' \longrightarrow$$

$$\longrightarrow CH_2=CH-C\equiv C-\overset{\displaystyle R}{\underset{\displaystyle R}{\overset{|}{\underset{|}{C}}}}-O-CH_2-CH_2OR'$$

(IX) $$CH_2=CH-C\equiv C-\overset{\displaystyle R}{\underset{\displaystyle R}{\overset{|}{\underset{|}{C}}}}-O-CH_2-CH_2OH + R'COOH \longrightarrow$$

$$\longrightarrow CH_2=CH-C\equiv C-\overset{\displaystyle R}{\underset{\displaystyle R}{\overset{|}{\underset{|}{C}}}}-O-CH_2-CH_2OCOR';$$

(X) $$CH_2-CH-C\equiv C-\overset{\displaystyle R}{\underset{\displaystyle R}{\overset{|}{\underset{|}{C}}}}-O-CH_2-CH_2OH + C_6H_4\begin{matrix}CO\\ \\ CO\end{matrix}O \longrightarrow$$

$$\longrightarrow C_6H_4\begin{matrix}COOH\\ \\ COOCH_2CH_2O\end{matrix}-\overset{\displaystyle R}{\underset{\displaystyle R}{\overset{|}{\underset{|}{C}}}}-C\equiv C-CH=CH_2.$$

compounds may be readily treated with alcohol to give a series of simple ethers. With the aid of mono-atomic alcohols, including ethyl, propyl, butyl, isobutyl, isomyl, allyl and benzyl alcohols, a number of simple ethers of vinylethenylcarbinols has been obtained. (See IV.)

All the above ethers, which are produced in a high degree of chemical purity, are liquids of great mobility, easily distilled in vacuo, are capable by the process of auto-polymerization to pass gradually into a gel, with the ultimate conversion to a resilient elastic mass, whose characteristics, to a considerable extent, depend on the nature of alcohol radical.

Again, it is of interest to note the influence of the structure upon the polymerization rate in combinations of this kind, associated with the active role played by the hydroxyl group; it is observed that esterification of a hydroxyl group, leading to its transformation into alkoxyl group, retards appreciably the speed of the reaction, in consequence of which the simple ethers polymerize at about one-fifth of the speed of the corresponding vinylethenylcarbinols.

In addition to the ethers of monohydric alcohols, Nazaroff and colleagues have also prepared the ethers of glycol. (See V.)

In this way there may be produced both the complete and partial glycol ethers. They are colourless, odourless, oily liquids, polymerizable on standing. The comparison of the polymerization rate of a complete and of partial glycol ethers shows that the latter ether polymerizes with far greater rapidity than does the complete ether, in spite of the presence in the latter of two vinylethenylcarbinol molecules, thus indicating that the absence of the hydroxyl is not compensated here even by an extra molecule

of the unsaturated vinylethenylcarbinol.

The ethers of glycol polymerize with a very great speed. Whereas a spontaneous polymerization of the methyl, ethyl and isoamyl ethers, in order to reach their ultimate stage of conversion to a hard, transparent body requires, approximately, from 60 to 70 days, the process in the case of the glycol ethers takes barely two days. The monoglycol and ethoxy ethers may also be derived from vinylethenylcarbinol and ethylene oxide. Furthermore, mono- and di-ethers of glycerol, as well as simple ethers of vinylethenylcarbinols, can be obtained. (See VI and VII).

Constitution

As to the structure of these combinations, it should be pointed out that the constitution of vinylethenylcarbinols has already been proved by Carothers by hydrating them to aliphatic alcohols. The structure of the ethers was proved by Nazaroff and his associates, who have demonstrated that simple ethers, on hydrolysis, give the original carbinols, while under the action of hydrogen chloride they yield vinylethenylcarbinylchlorides and the corresponding alcohols. The same vinylethenylcarbinylchlorides are also obtained directly from a carbinol and hydrochloric acid; consequently, this reaction of hydrolysis with hydrochloric or sulphuric acid testifies that in the process of the esterifying of the vinylethenylcarbinol there occurs no regrouping whatever. Note should be made of the fact that whereas glycol ethers are hydrolized with extreme ease, the ethers of monohydric alcohols undergo hydrolysis with greater difficulty.

A large range of polymerizable products with interesting film-forming properties has also been secured by the esterification of vinylethenylcarbinols with the aid of glycol monoethers, yielding the corresponding beta-alkoxyethyl ethers of the vinylethenylcarbinols (see VIII).

It is also interesting that monoglycol and ethoxy ethers of vinylethenylcarbinols provide us with great possibilities of obtaining an unlimited range of new polymeric products of merit through the application of the esterification reaction by means of any acid. For example, the action of acetic acid results in a crystal-clear, colourless polymer (see IX). The interaction with phthalic anhydride is also given in X.

(To be continued)

PLASTICS IN ENGINEERING

In a paper on the above subject, read before the Society of Engineers at Burlington House on May 7, 1945, Dr. Yarsley devoted the first part of his talk to a consideration of plastic materials commercially available, and a brief description of some of the methods operated for their application. He endeavoured to counteract some of the erroneous ideas about these materials of construction which have grown up in recent years, mainly on account of over zealous propaganda and the secrecy which has been enforced during war-time. These new materials are not likely to sweep away conventional materials of construction, but wisely applied they can aid the engineer to overcome many long-standing difficulties. Plastics are relatively expensive materials, so that they can be applied logically and economically only in " key " roles.

Dr. Yarsley dealt with some of the more recent applications of plastics in various fields of engineering, and in particular the use of plastic adhesives and cements. From relatively small beginnings this branch of the industry has grown rapidly during the past two years, and it may be claimed to have revolutionized what was once known as the plywood industry. The Mosquito bomber is an outstanding monument to the service possibilities of plastic adhesives. Even more revolutionary from the conservative engineering viewpoint is the use of plastic bonding agents for securing metal to wood and metal to metal. It has been proved that, for certain purposes, plastic bonded metal-to-metal joints are superior to riveted or welded joints, and already the uses of these materials in bonding extruded aluminium rod in the production of window and cycle frames have passed beyond the experimental stage.

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